(12) **United States Patent**
Omae et al.

(10) **Patent No.: US 11,996,344 B2**
(45) **Date of Patent: May 28, 2024**

(54) **SEMICONDUCTOR DEVICE**

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(73) Assignee: **DENSO CORPORATION**, Kariya (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 464 days.

(21) Appl. No.: **17/469,091**

(22) Filed: **Sep. 8, 2021**

(65) **Prior Publication Data**

US 2021/0407881 A1 Dec. 30, 2021

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2020/005569, filed on Feb. 13, 2020.

(30) **Foreign Application Priority Data**

Mar. 11, 2019 (JP) 2019-043884

(51) **Int. Cl.**

H01L 23/367	(2006.01)
H01L 23/00	(2006.01)
H01L 23/31	(2006.01)
H01L 23/495	(2006.01)

(52) **U.S. Cl.**
CPC ***H01L 23/367*** (2013.01); ***H01L 23/3107*** (2013.01); ***H01L 23/49517*** (2013.01); ***H01L 23/49537*** (2013.01); ***H01L 23/49562*** (2013.01); ***H01L 24/40*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. H01L 23/367; H01L 23/49517; H01L 24/44
See application file for complete search history.

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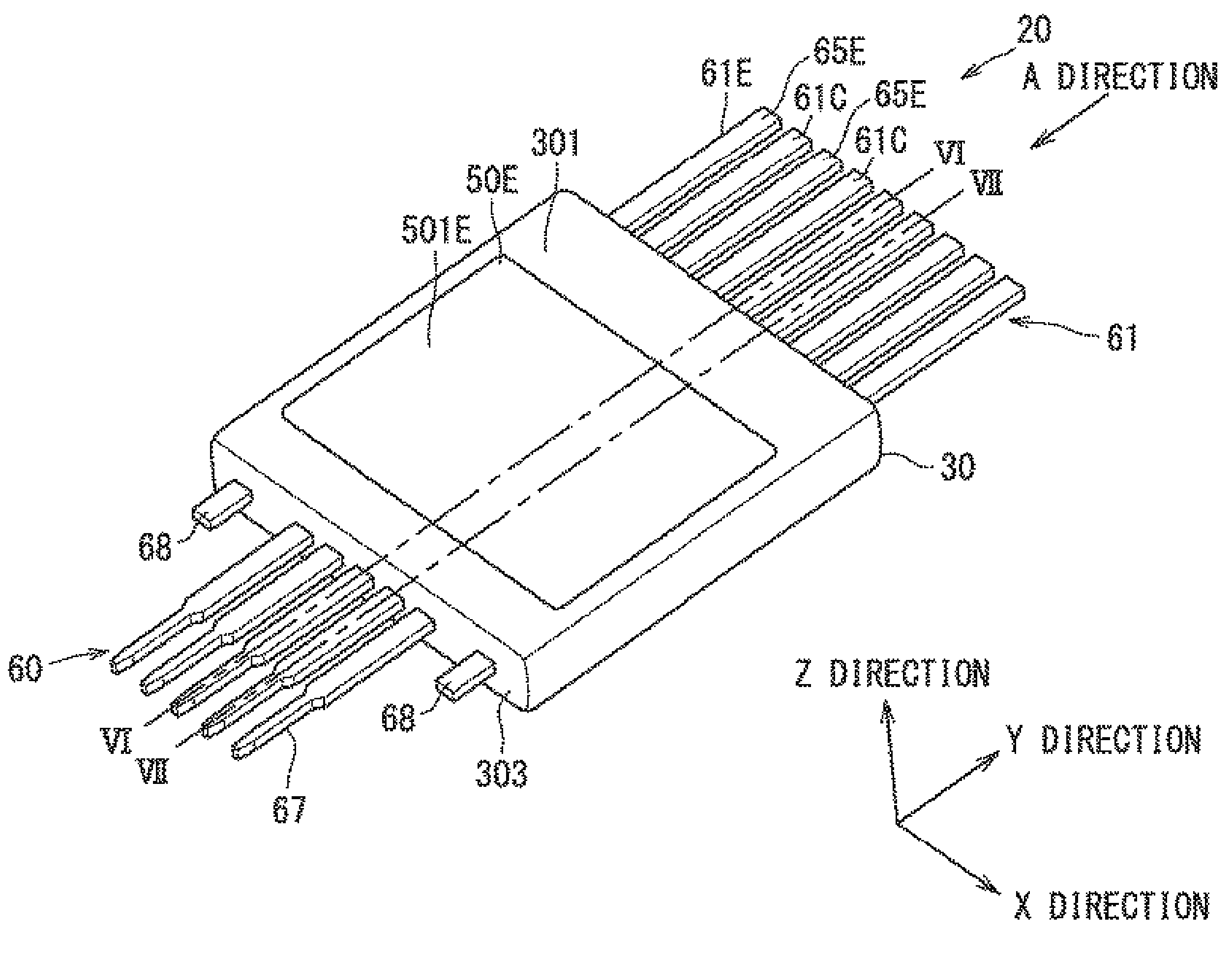
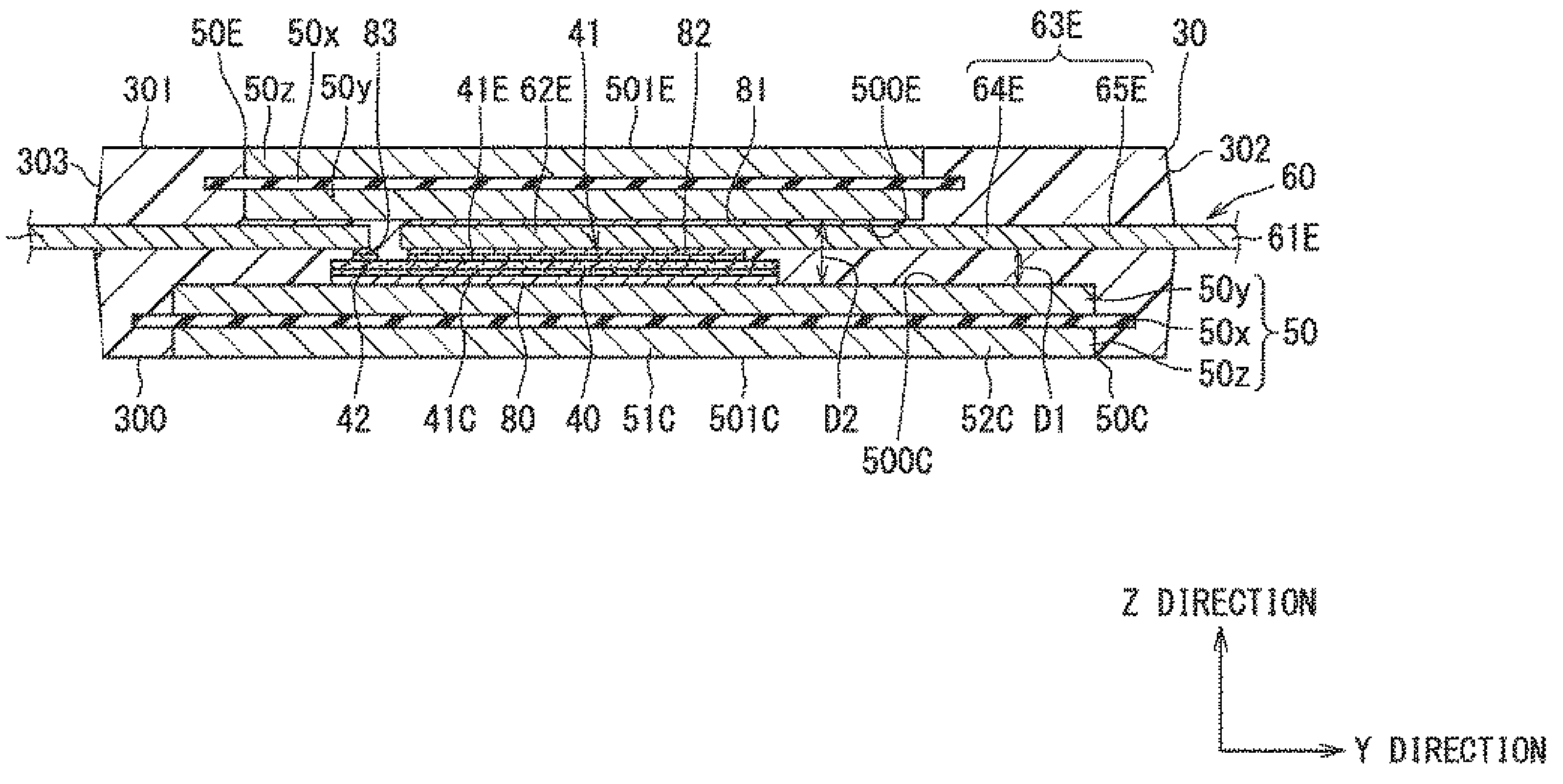
(57) **ABSTRACT**

A semiconductor device includes: a semiconductor element having a first main electrode and a second main electrode; a first heat dissipation member and a second heat dissipation member; and a lead frame including a first main terminal connected to the first heat dissipation member and a second main terminal connected to the second main electrode. The second main terminal includes a connection portion connected with the second main electrode, a facing portion extending from the connection portion and facing the first heat dissipation member, and a non-facing portion. The non-facing portion and the first main terminal are arranged in a direction orthogonal to a thickness direction. A side surface of the first main terminal and a side surface of the non-facing portion of the second main terminal face each other.

7 Claims, 14 Drawing Sheets





(52) **U.S. Cl.**
CPC *H01L 2924/1305* (2013.01); *H01L 2924/13091* (2013.01); *H01L 2924/181* (2013.01)

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FIG. 1

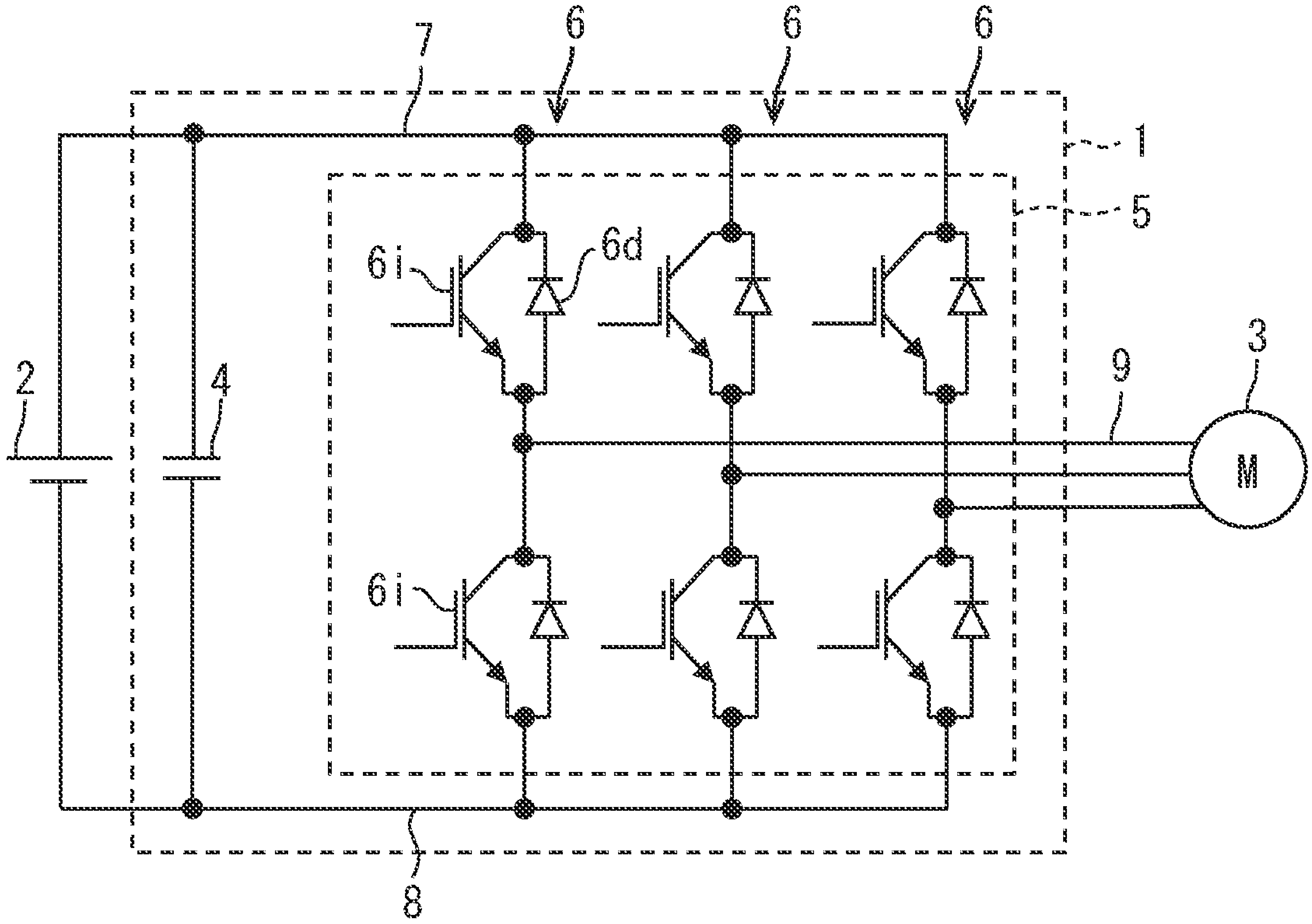


FIG. 2

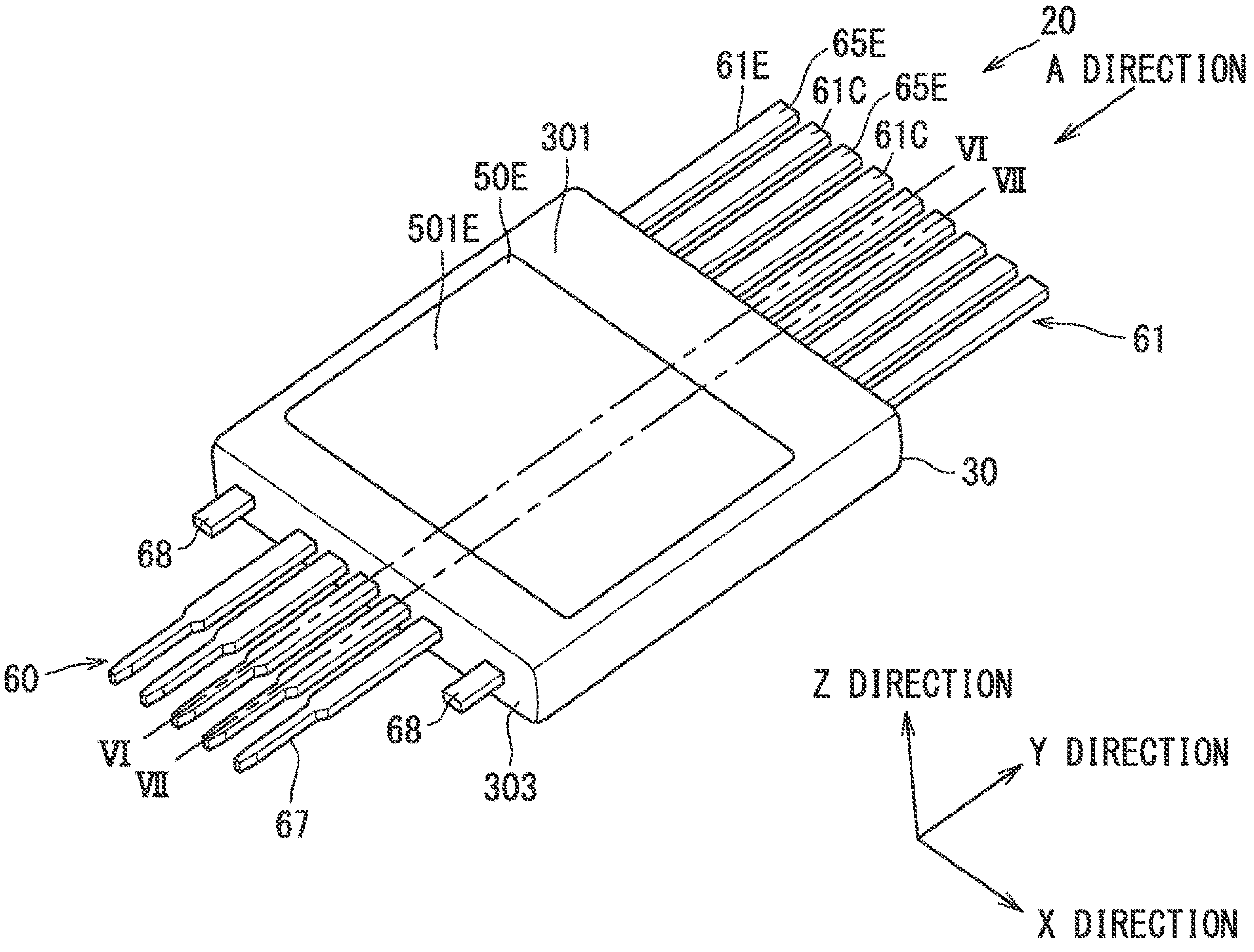

20
A DIRECTION
61E
65E
61C
65E
61C
VI
VII
301
50E
501E
61
30
68
60
VI
VII
67
68
303
Z DIRECTION
Y DIRECTION
X DIRECTION

FIG. 3

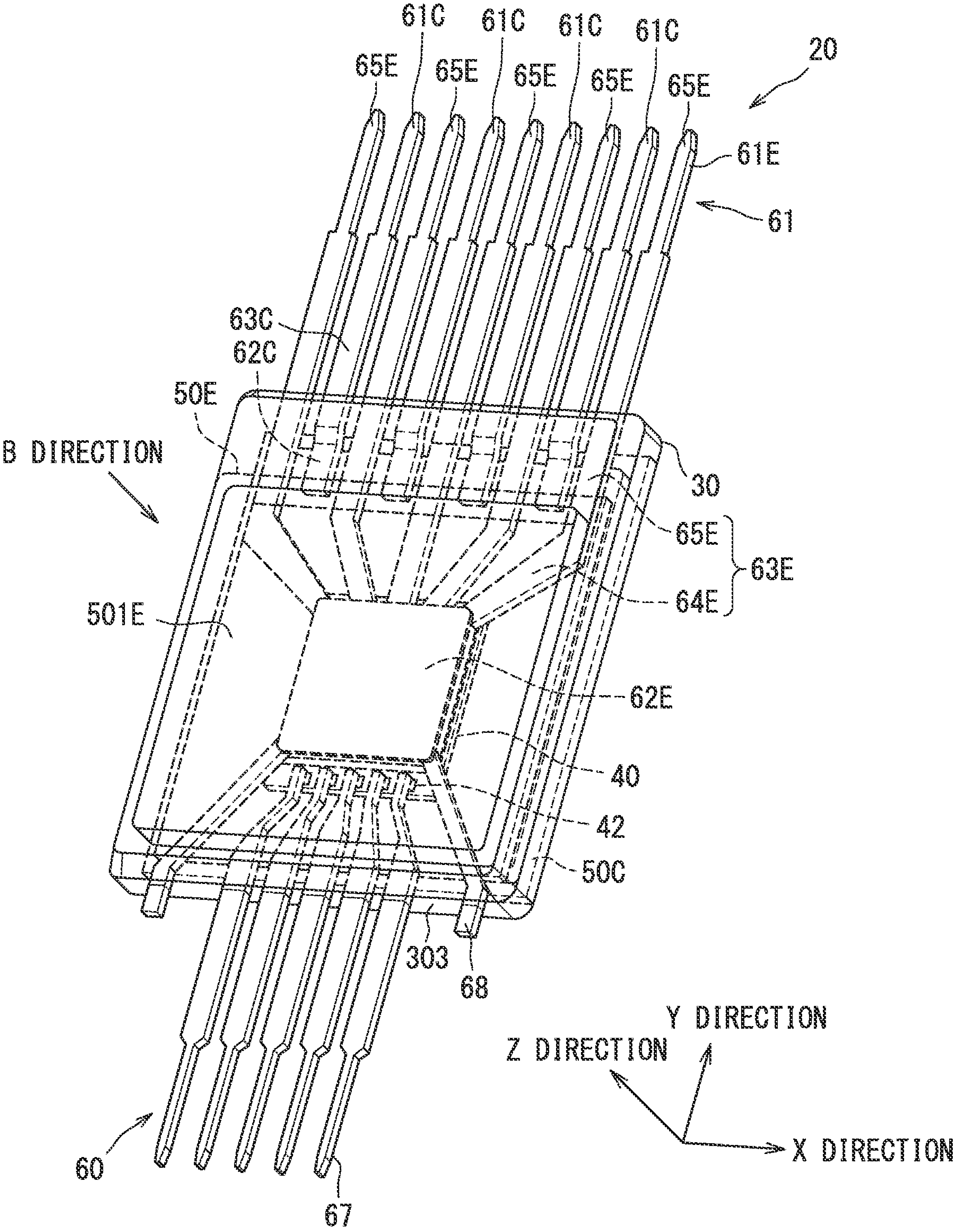

61C
61C
61C
61C
20
65E
65E
65E
65E
65E
61E
61
63C
62C
50E
B DIRECTION
30
65E
63E
64E
501E
62E
40
42
50C
303
68
Y DIRECTION
Z DIRECTION
X DIRECTION
60
67

FIG. 4

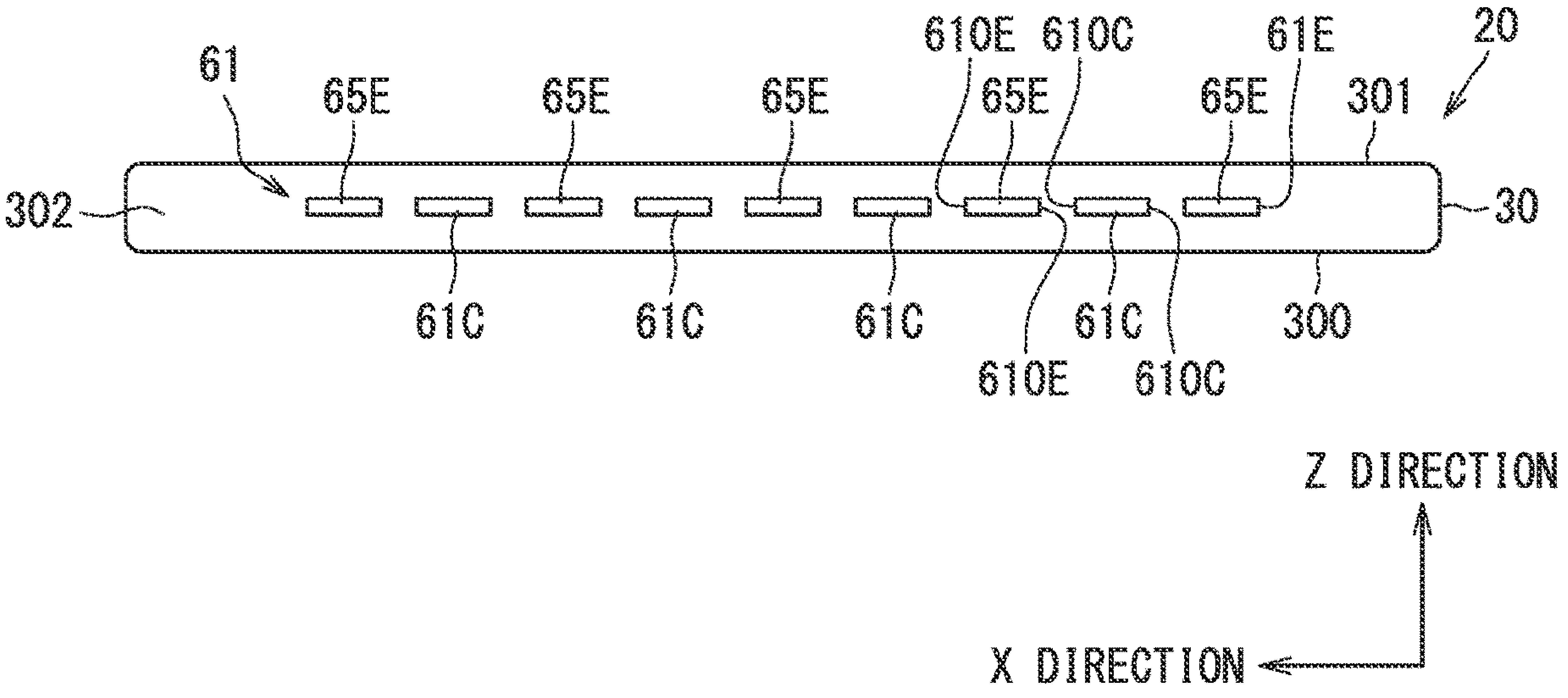

610E
610C
61E
20
61
65E
65E
65E
65E
65E
301
302
30
61C
61C
61C
61C
300
610E
610C
Z DIRECTION
X DIRECTION

FIG. 5

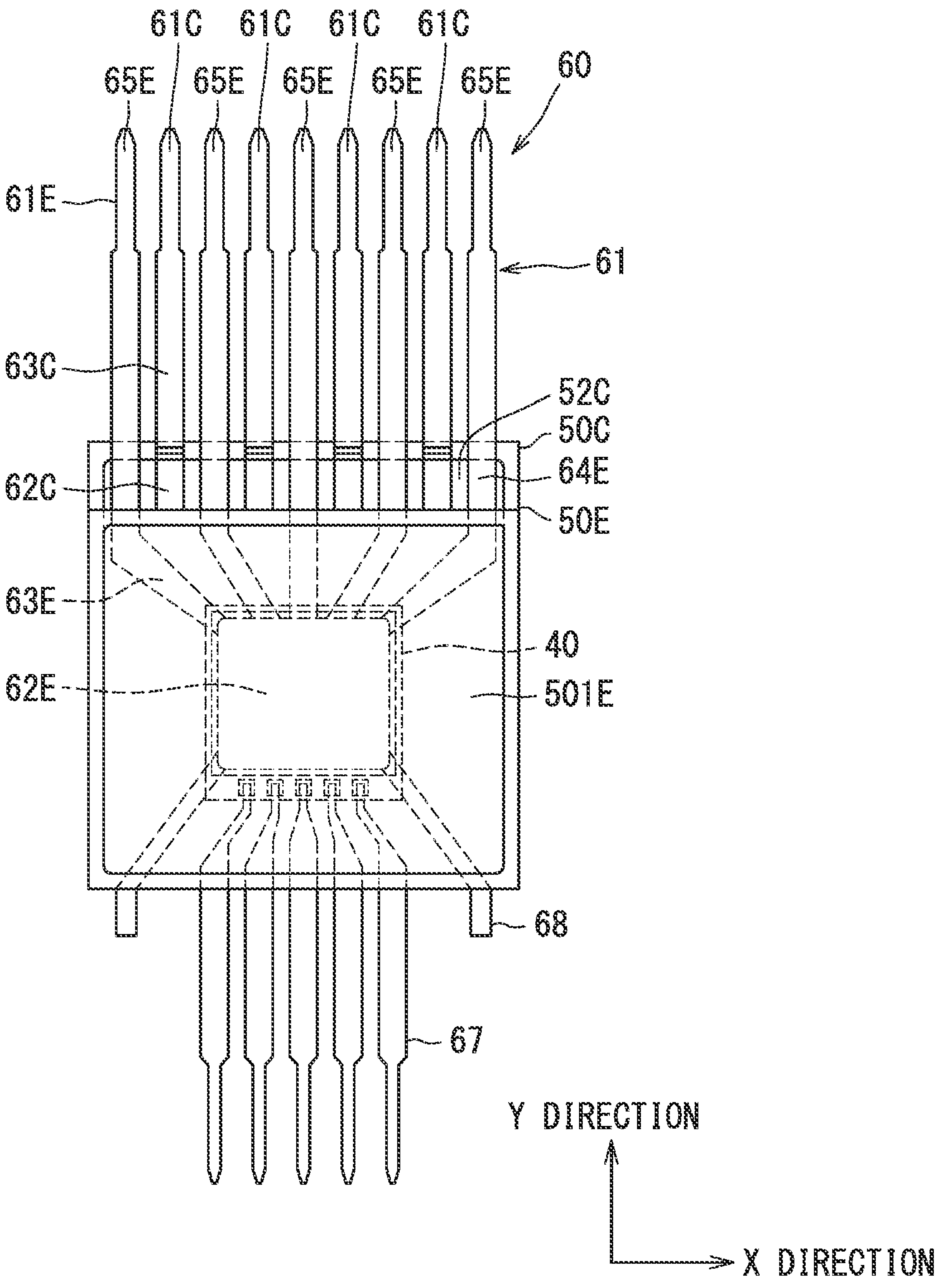

61C
61C
61C
61C
65E
65E
65E
65E
65E
60
61E
61
63C
52C
50C
62C
64E
50E
63E
40
62E
501E
68
67
Y DIRECTION
X DIRECTION

FIG. 6

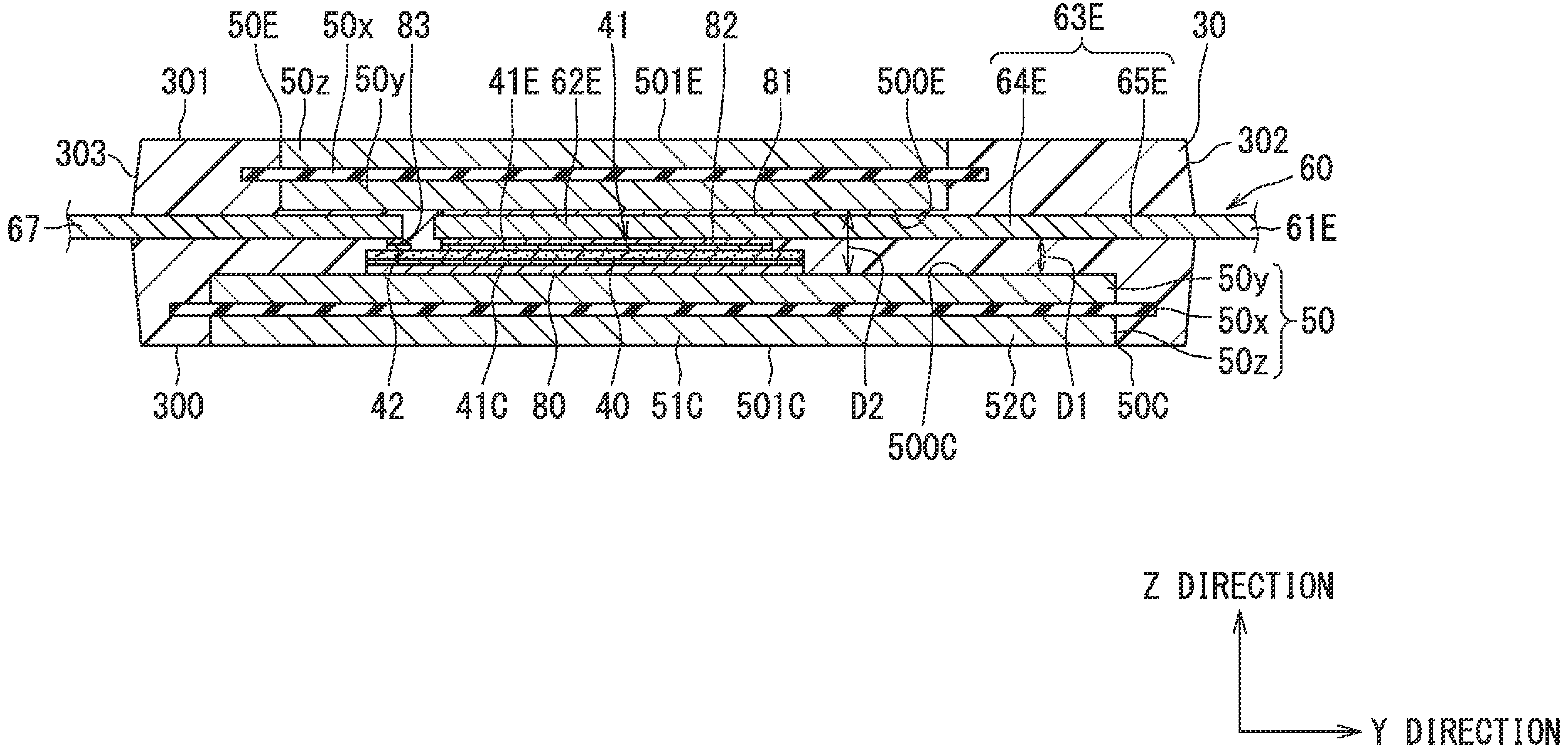

50E
50x
83
41
82
63E
30
301
50z
50y
41E
62E
501E
81
500E
64E
65E
303
302
60
67
61E
50y
50x
50
50z
300
42
41C
80
40
51C
501C
D2
500C
52C
D1
50C
Z DIRECTION
Y DIRECTION

FIG. 7

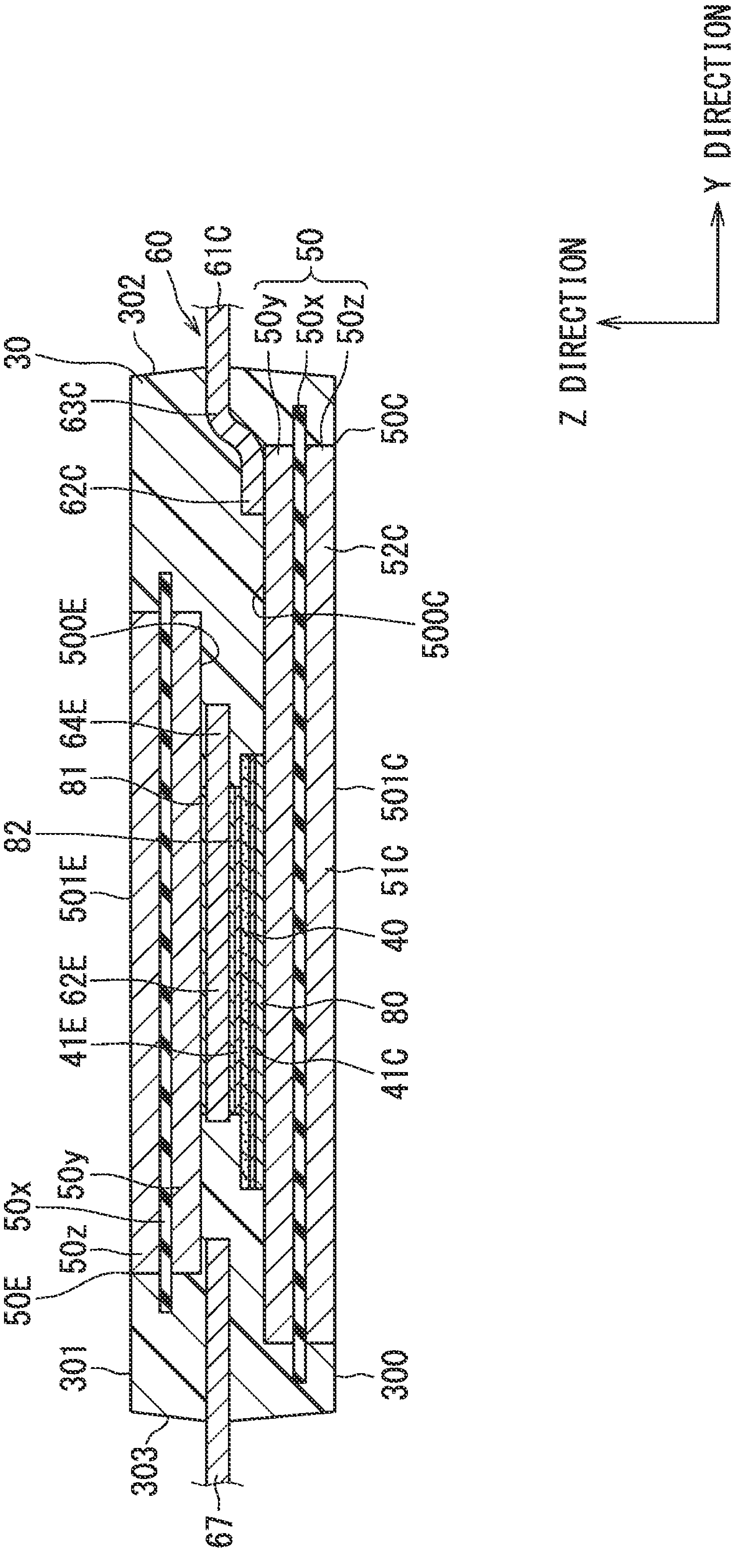

30
302
60
61C
50
50y
50x
50z
63C
50C
62C
52C
500C
500E
64E
81
82
501C
501E
51C
40
62E
80
41E
41C
50x
50y
50z
50E
301
300
303
67
Z DIRECTION
Y DIRECTION

FIG. 8

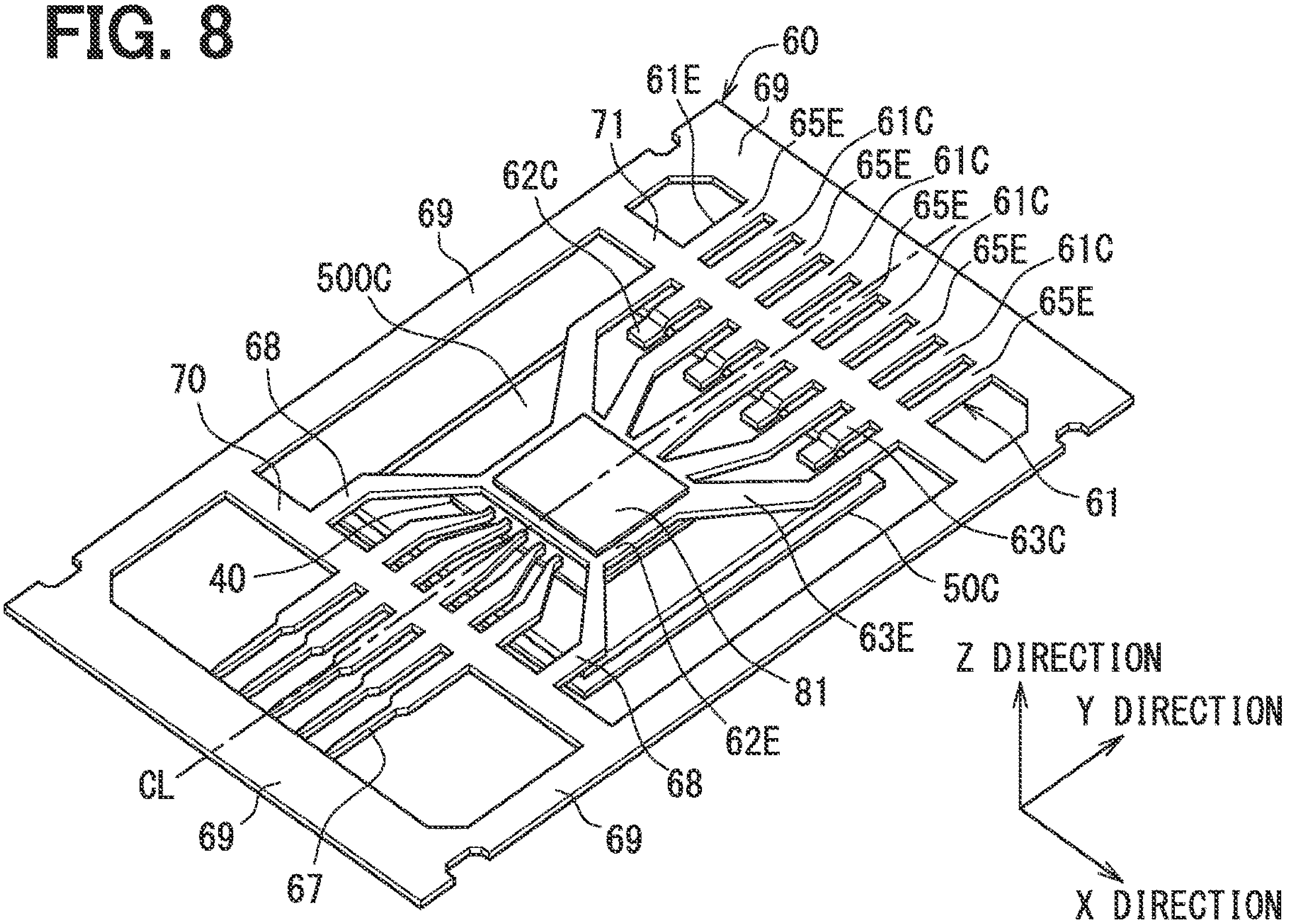

60
61E
69
71
65E
61C
65E
61C
62C
65E
61C
69
65E
61C
500C
65E
68
70
61
40
63C
50C
63E
Z DIRECTION
Y DIRECTION
81
62E
CL
68
69
69
67
X DIRECTION

FIG. 9

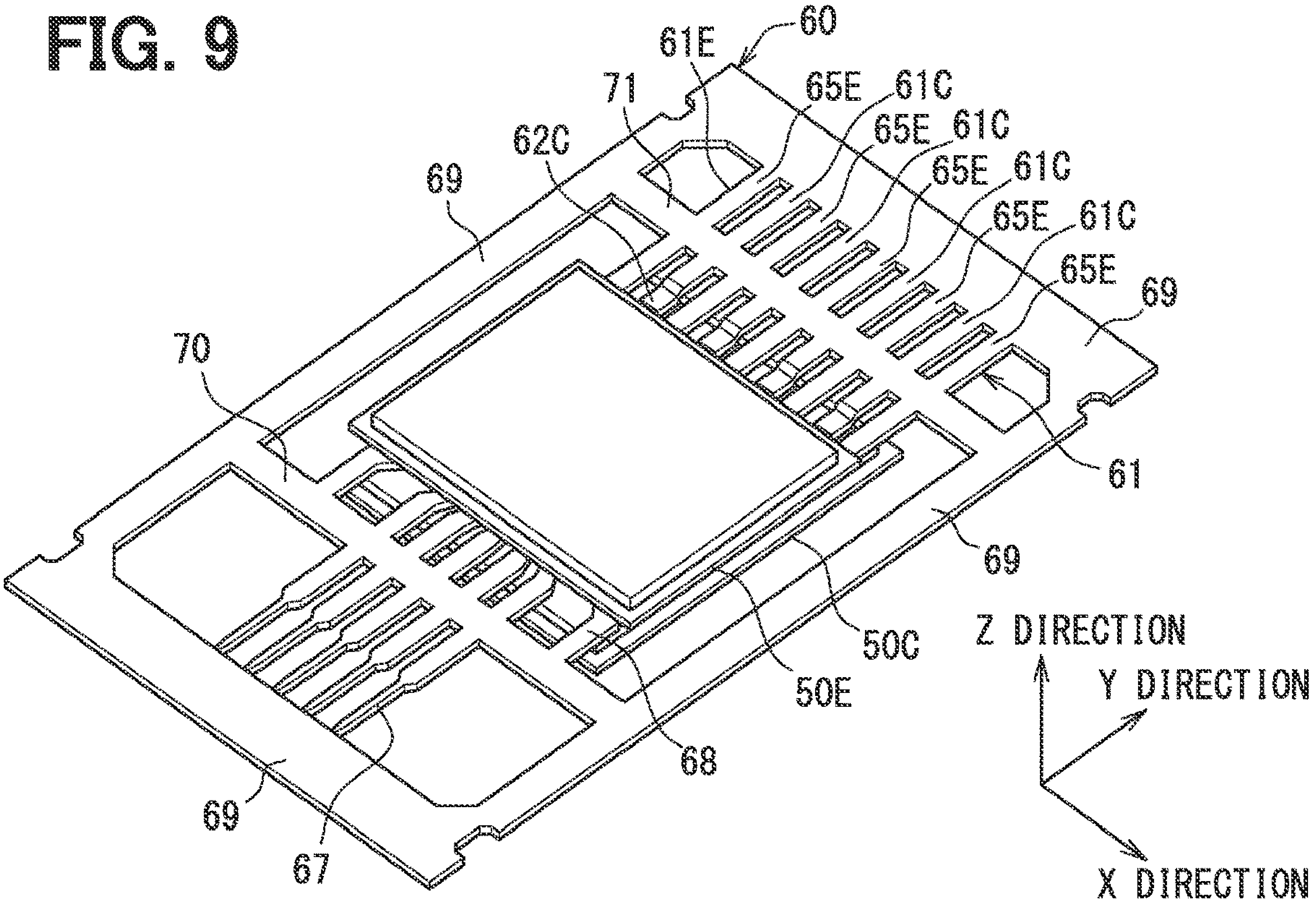

60
61E
71
65E
61C
65E
61C
62C
65E
61C
69
65E
61C
65E
69
70
61
69
50C
Z DIRECTION
Y DIRECTION
50E
68
69
67
X DIRECTION

FIG. 10

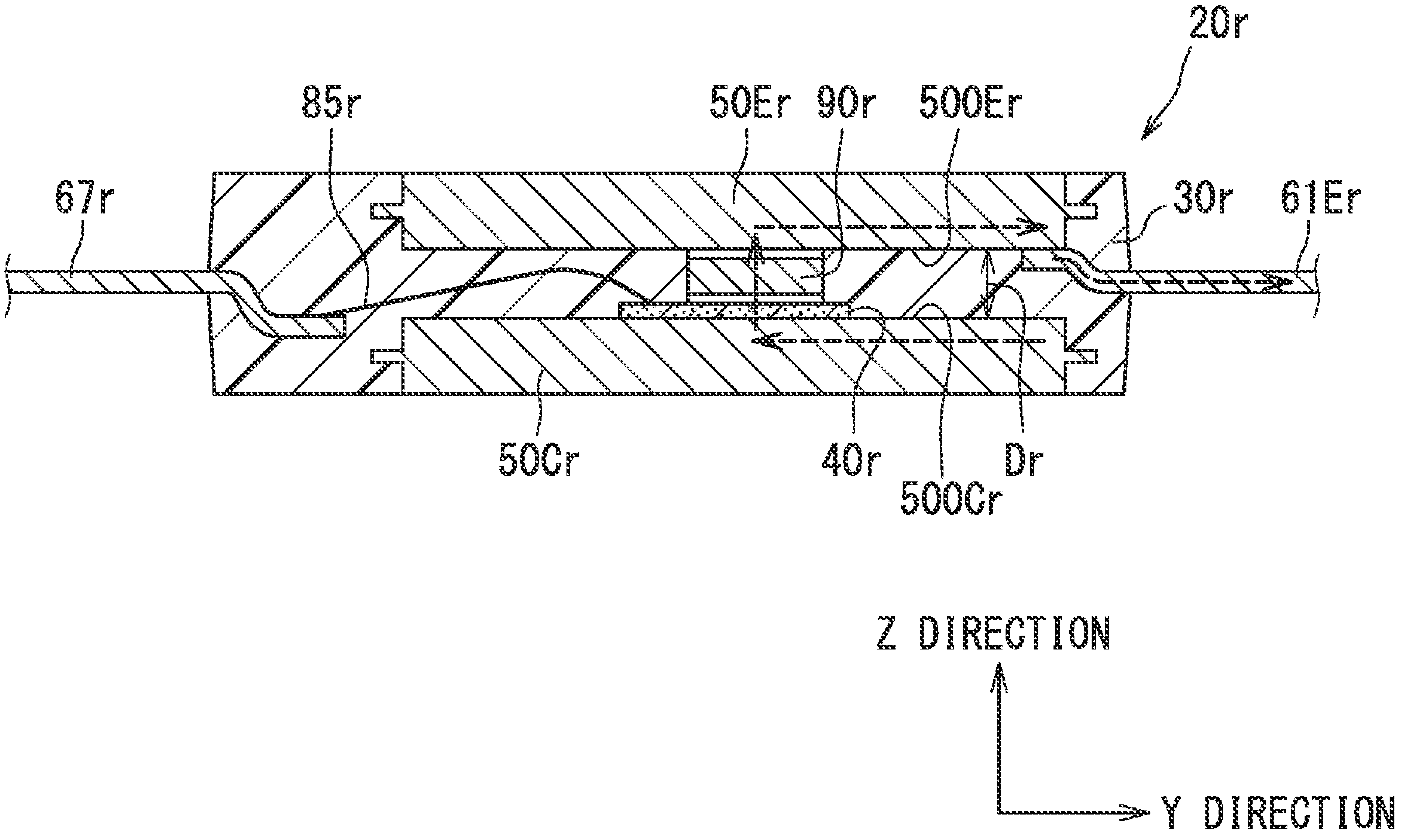

20r
85r
50Er
90r
500Er
67r
30r
61Er
50Cr
40r
500Cr
Dr
Z DIRECTION
Y DIRECTION

FIG. 11

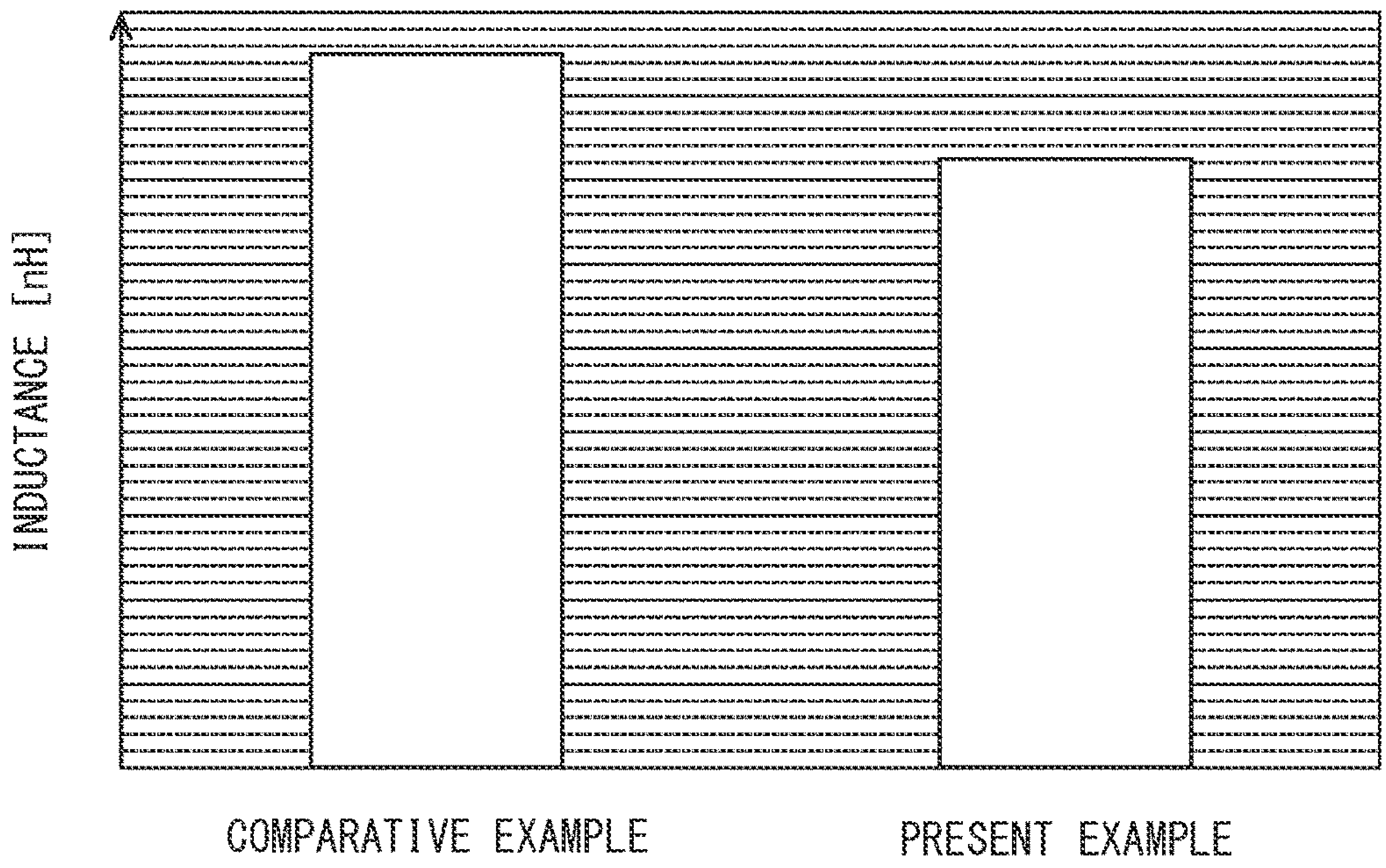

INDUCTANCE [nH]
COMPARATIVE EXAMPLE
PRESENT EXAMPLE

FIG. 12

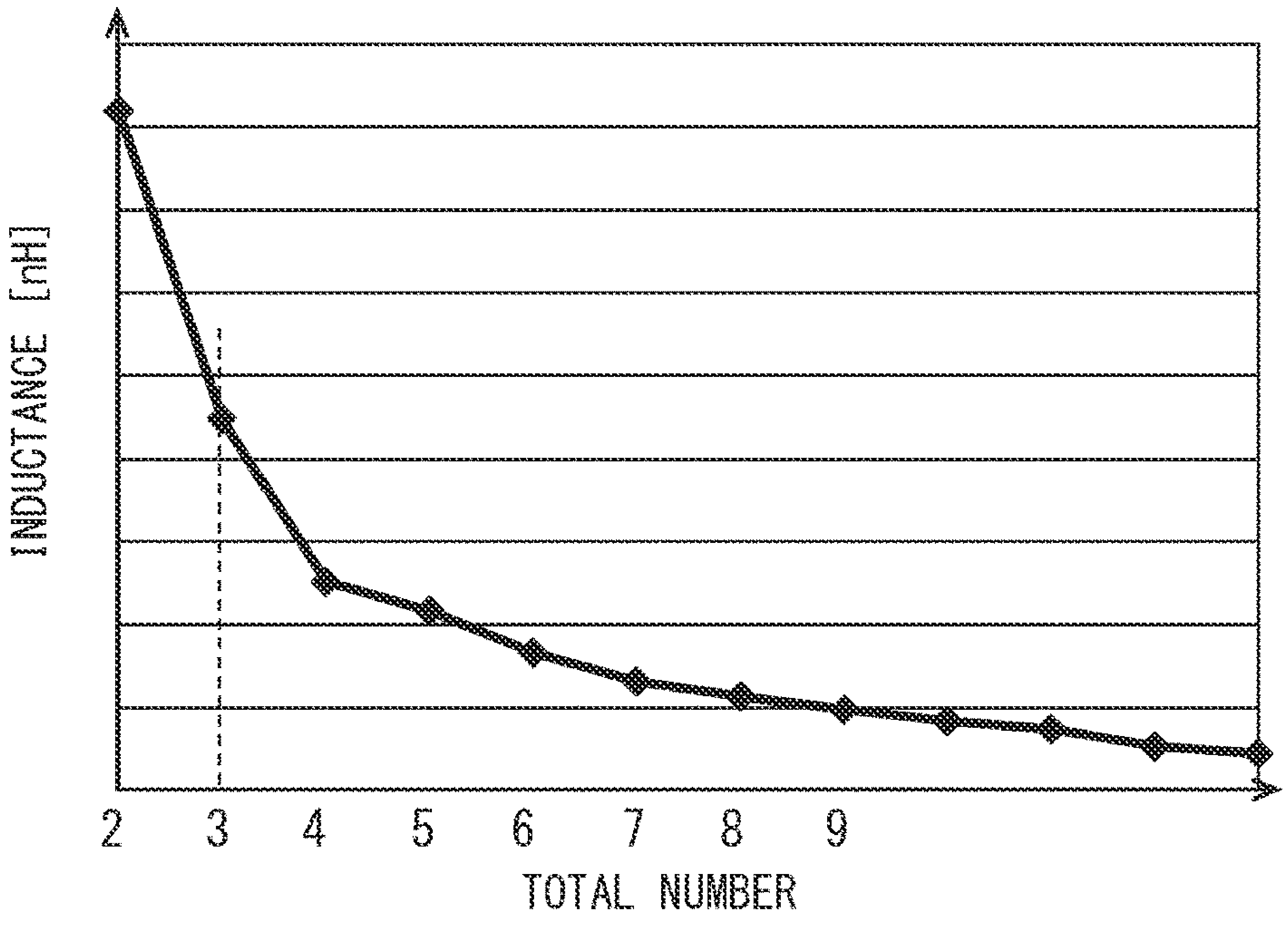

INDUCTANCE [nH]
2
3
4
5
6
7
8
9
TOTAL NUMBER

FIG. 13

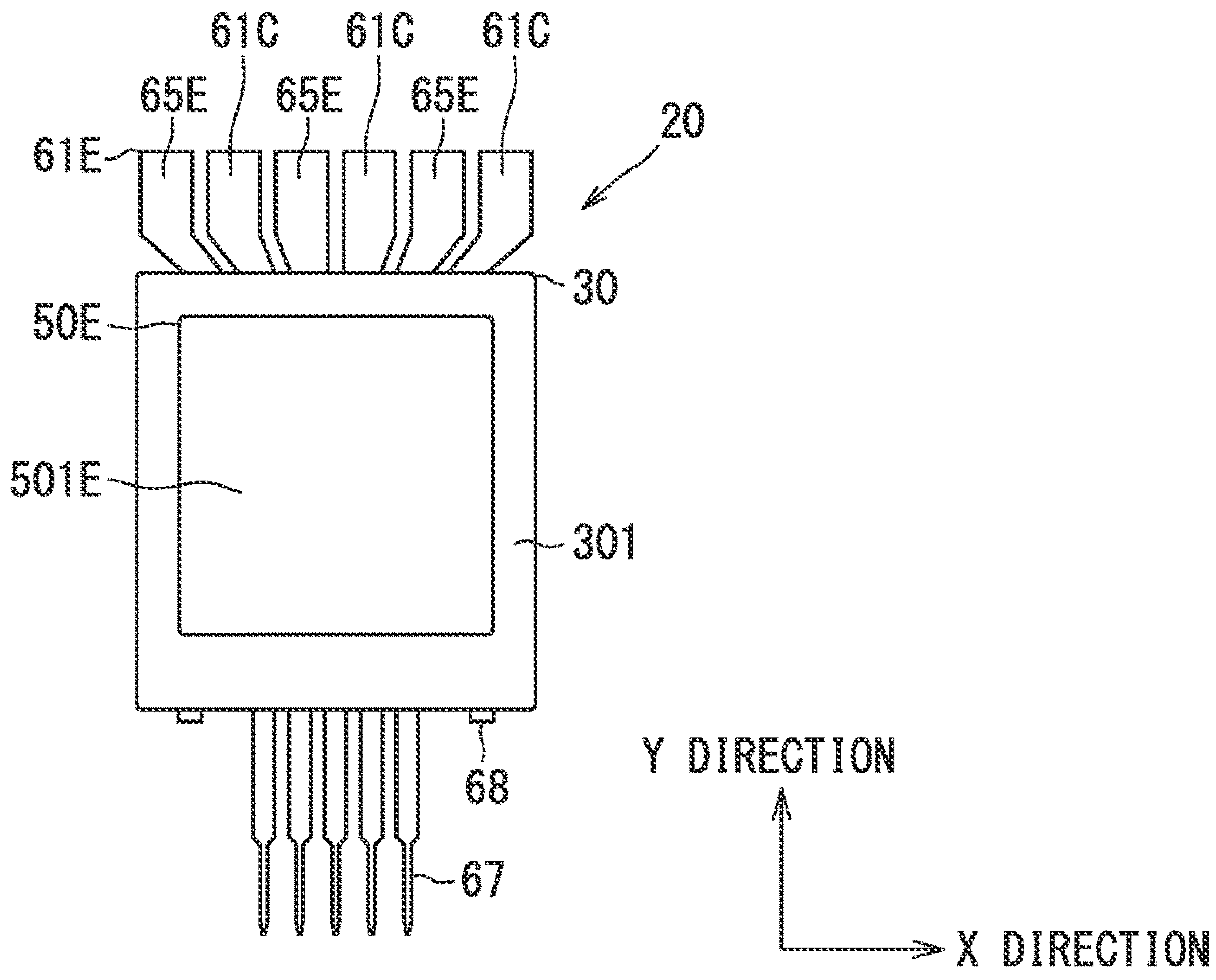

61C
61C
61C
65E
65E
65E
61E
20
30
50E
501E
301
68
67
Y DIRECTION
X DIRECTION

FIG. 14

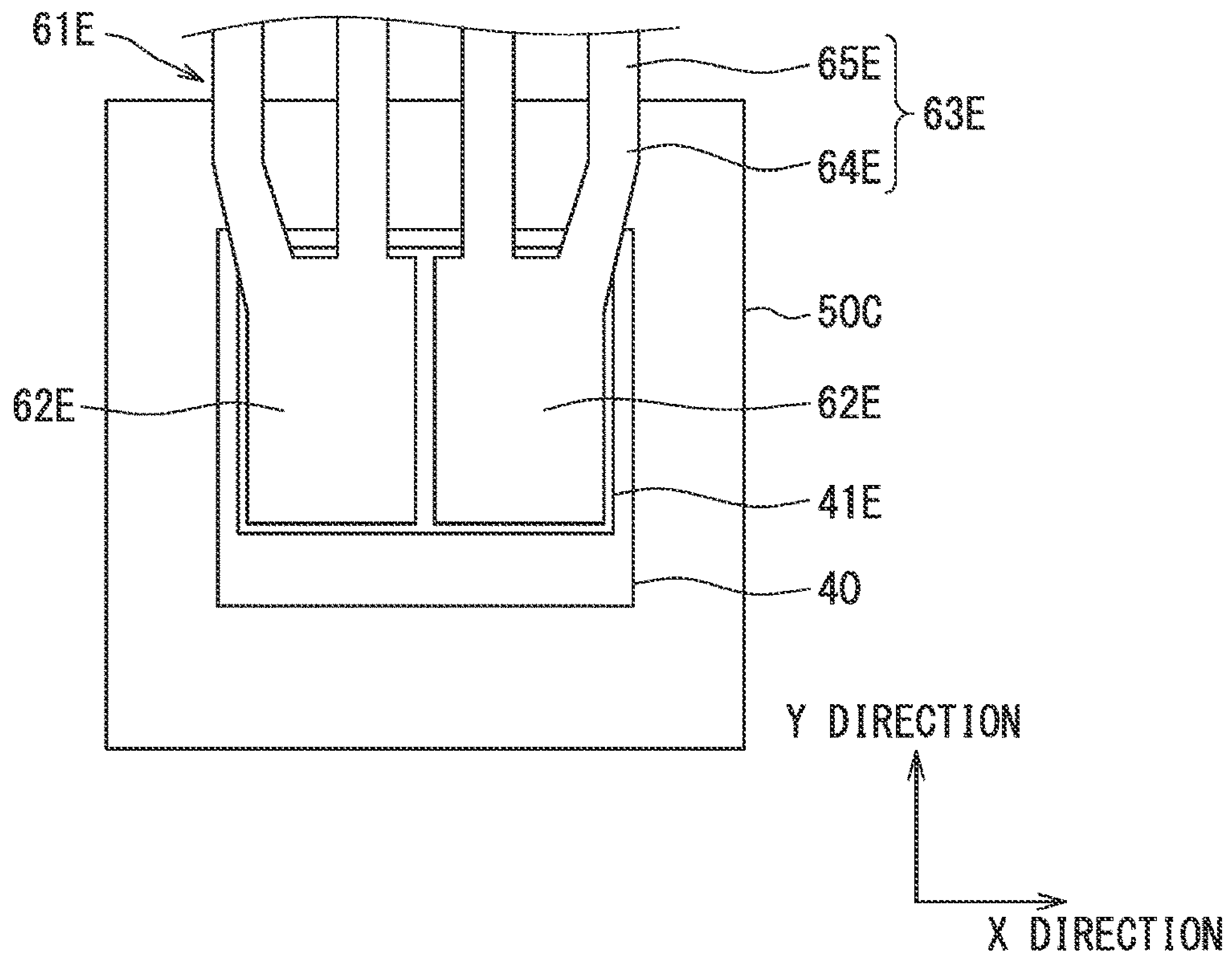

61E
65E
64E
63E
50C
62E
62E
41E
40
Y DIRECTION
X DIRECTION

FIG. 15

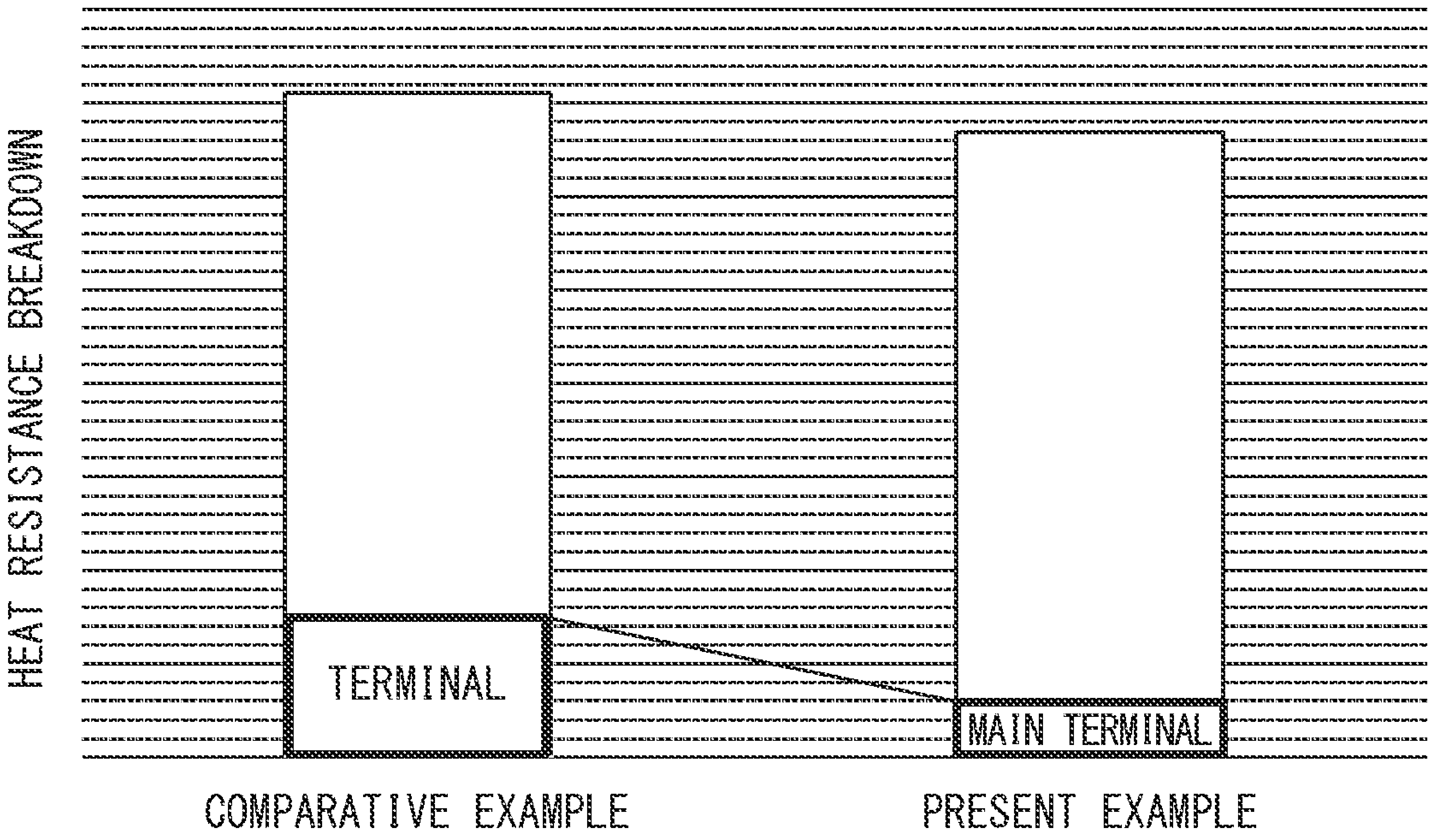

HEAT RESISTANCE BREAKDOWN
TERMINAL
MAIN TERMINAL
COMPARATIVE EXAMPLE
PRESENT EXAMPLE

FIG. 16

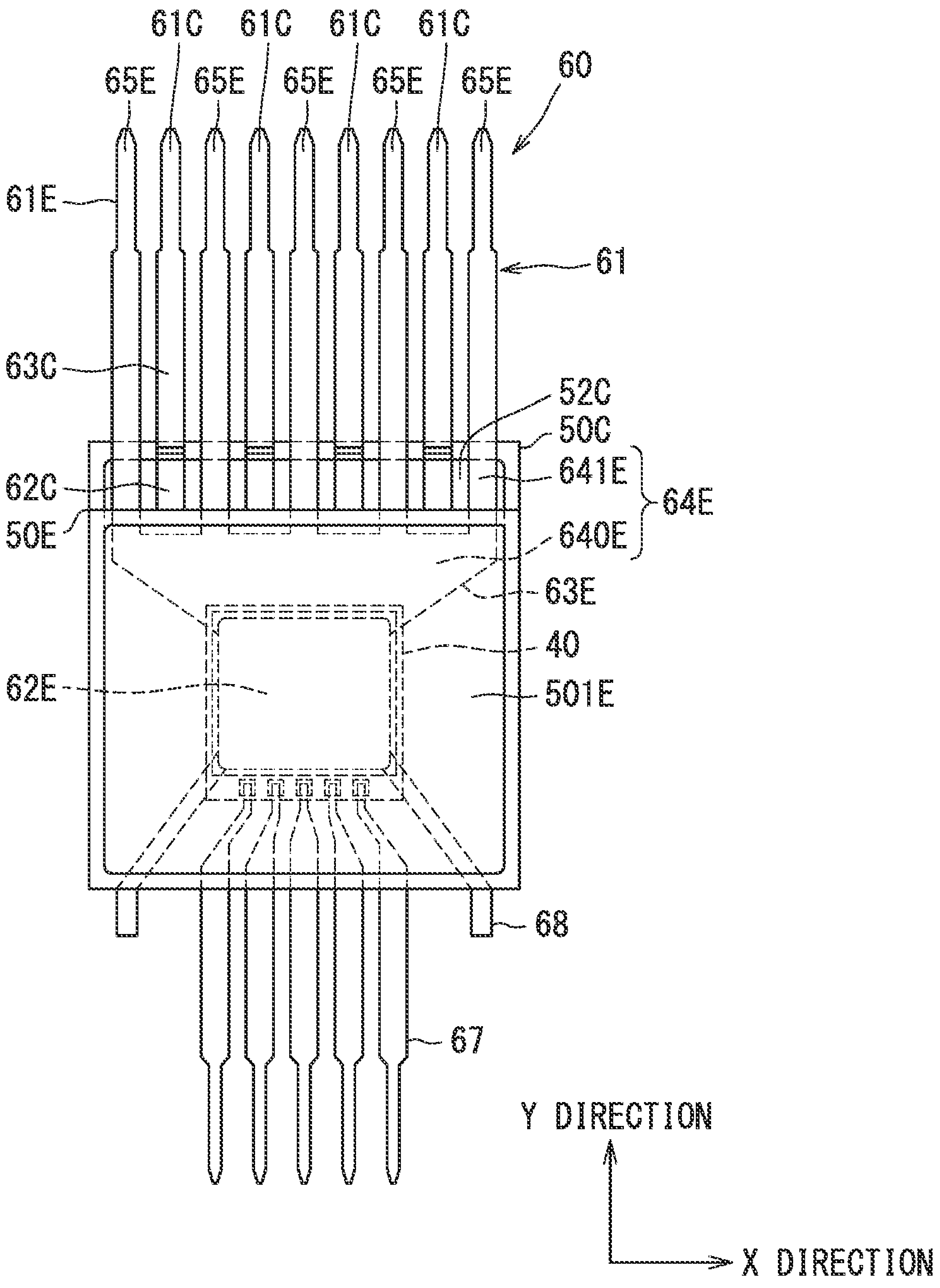

61C
61C
61C
61C
65E
65E
65E
65E
65E
60
61E
61
63C
52C
50C
62C
641E
64E
50E
640E
63E
40
62E
501E
68
67
Y DIRECTION
X DIRECTION

FIG. 17

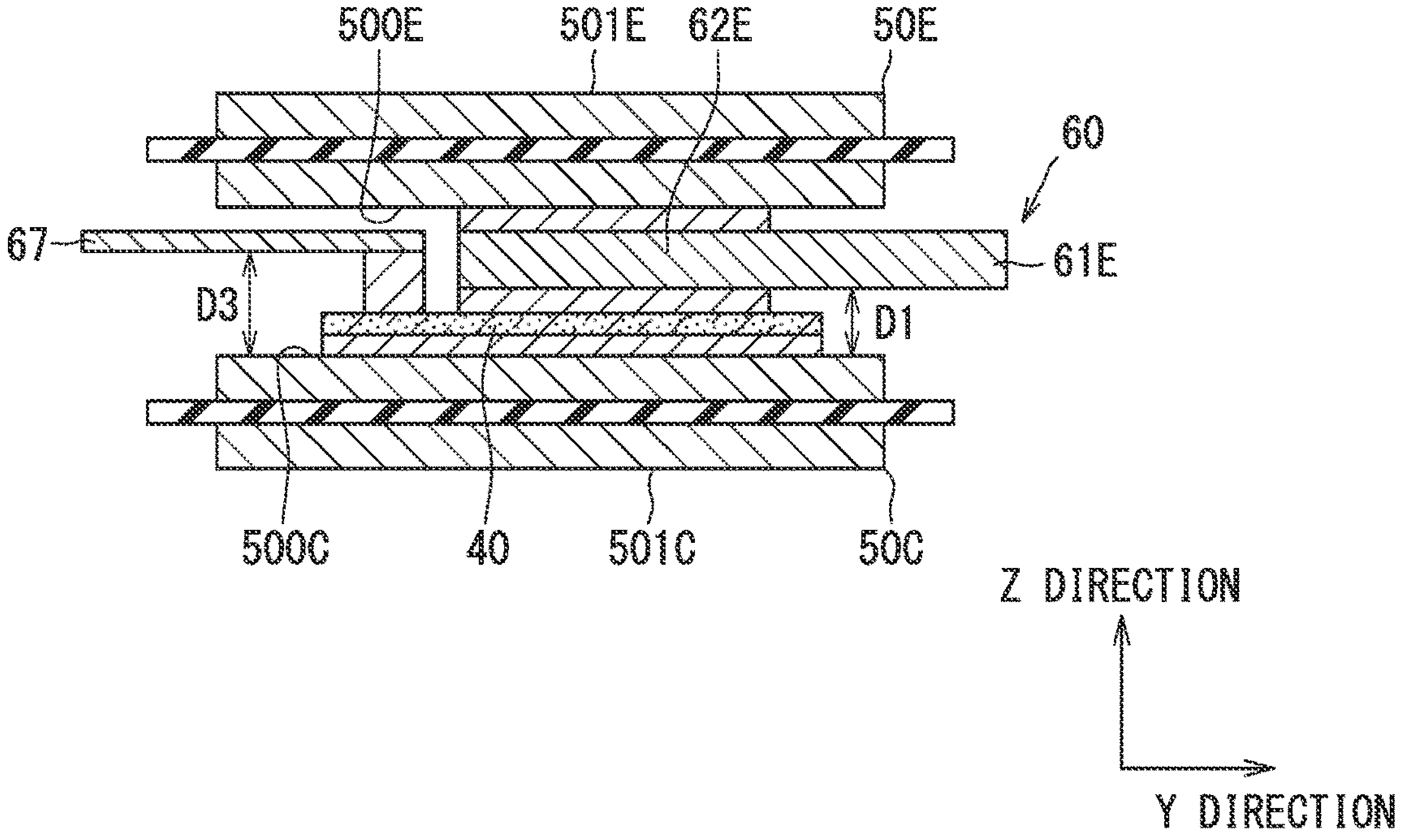
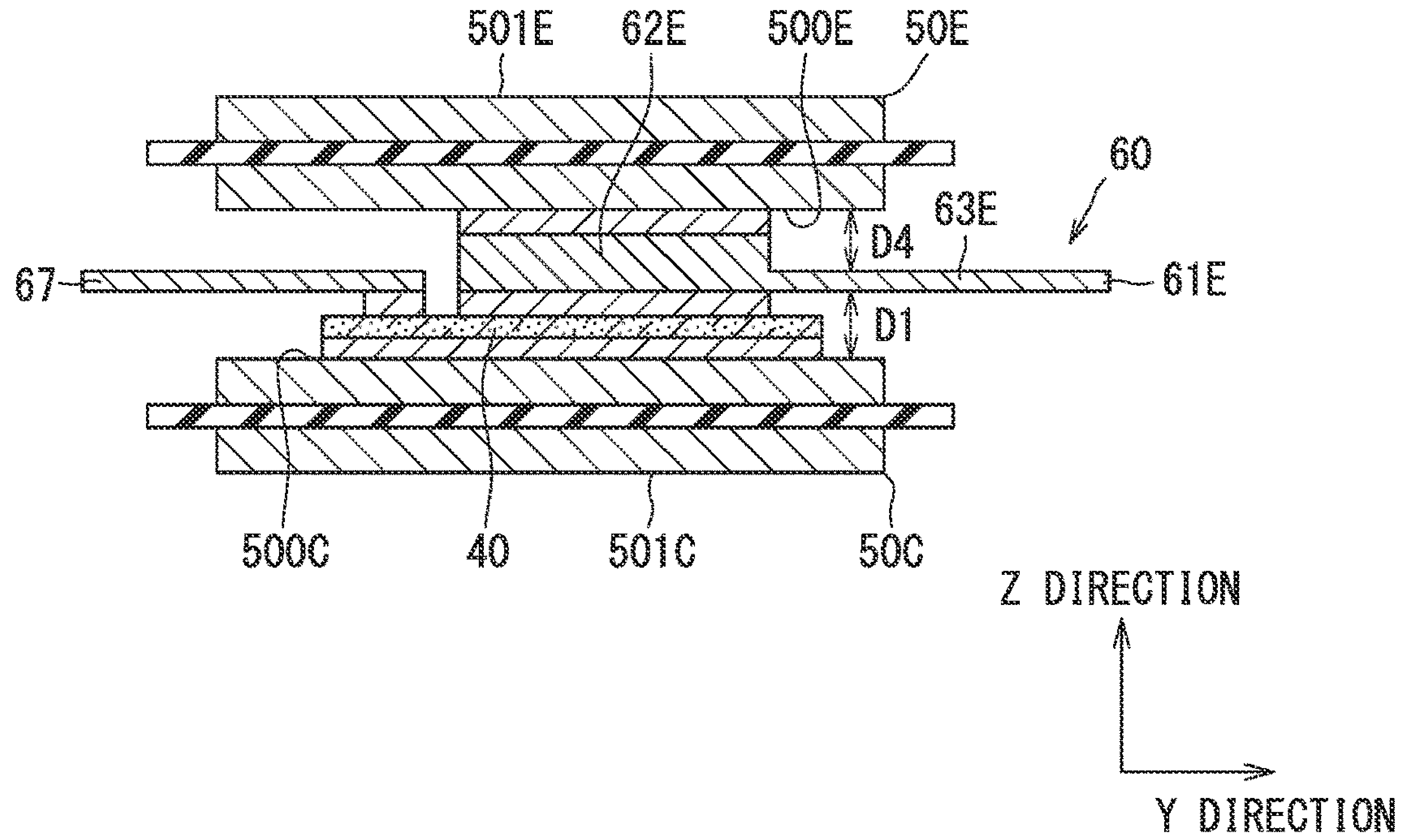

500E
501E
62E
50E
60
67
61E
D3
D1
500C
40
501C
50C
Z DIRECTION
Y DIRECTION

FIG. 18


501E
62E
500E
50E
60
63E
D4
67
61E
D1
500C
40
501C
50C
Z DIRECTION
Y DIRECTION

SEMICONDUCTOR DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation application of International Patent Application No. PCT/JP2020/005569 filed on Feb. 13, 2020, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2019-043884 filed on Mar. 11, 2019. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a semiconductor device.

BACKGROUND

There has been known a semiconductor device including a semiconductor element having multiple main electrodes, multiple heat dissipation members placed so as to sandwich the semiconductor element, and multiple main terminals electrically connected to the main electrodes, respectively.

SUMMARY

The present disclosure provides a semiconductor device including: a semiconductor element having a first main electrode and a second main electrode; a first heat dissipation member and a second heat dissipation member; and a lead frame including a first main terminal connected to the first heat dissipation member and a second main terminal connected to the second main electrode. The second main terminal includes a connection portion connected with the second main electrode, a facing portion extending from the connection portion and facing the first heat dissipation member, and a non-facing portion. The non-facing portion and the first main terminal are arranged in a direction orthogonal to a thickness direction. A side surface of the first main terminal and a side surface of the non-facing portion of the second main terminal face each other.

BRIEF DESCRIPTION OF DRAWINGS

Objects, features and advantages of the present disclosure will become apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1** is a diagram showing a schematic configuration of an electric power conversion device to which a semiconductor device according to a first embodiment is applied;

FIG. **2** is a perspective view showing a semiconductor device;

FIG. **3** is a perspective view showing elements inside a sealing resin body;

FIG. **4** is a plan view of FIG. **2** as seen from an A direction;

FIG. **5** is a plan view of FIG. **3** as seen from a B direction;

FIG. **6** is a cross-sectional view of the semiconductor device taken along a line VI-VI in FIG. **2**;

FIG. **7** is a cross-sectional view taken along a line VII-VII in FIG. **2**;

FIG. **8** is a perspective view showing a connection state of a lead frame;

FIG. **9** is a perspective view showing a positional relationship between each heat sink and a lead frame;

FIG. **10** is a cross-sectional view showing a comparative example;

FIG. **11** is a diagram showing an inductance reduction;

FIG. **12** is a diagram showing an inductance reduction;

FIG. **13** is a plan view showing a modification;

FIG. **14** is a schematic plan view showing the modification;

FIG. **15** is a diagram showing a heat resistance reduction.

FIG. **16** is a plan view showing a semiconductor device according to a second embodiment and corresponding to FIG. **5**;

FIG. **17** is a cross-sectional view showing the periphery of a semiconductor element in a semiconductor device according to a third embodiment; and

FIG. **18** is a cross-sectional view showing the modification.

DETAILED DESCRIPTION

A semiconductor device according to an example includes a semiconductor element having a first main electrode and a second main electrode, a heat dissipation member placed so as to sandwich the semiconductor element, and main terminals electrically connected to corresponding main electrodes, respectively.

The semiconductor device includes, as the heat dissipation member, a first heat dissipation member placed close to the first main electrode and a second heat dissipation member placed close to the second main electrode. The semiconductor device includes, as the main terminal, a first main terminal electrically connected to the first main electrode and a second main terminal electrically connected to the second main electrode.

In the semiconductor device described above, the first main terminal extends from the first heat dissipation member, and the second main terminal extends from the second heat dissipation member. The first heat dissipation member is connected to the first main electrode, and the second heat dissipation member is connected to the second main electrode via a terminal. Between the first heat dissipation member and the second heat dissipation member, the semiconductor element and the terminal are interposed. Further, the semiconductor device includes one first main terminal and one second main terminal. It is required to further reduce the inductance.

A semiconductor device according to an aspect of the present disclosure includes: a semiconductor element having one surface and a back surface opposite to the one surface in a thickness direction of the semiconductor element, the semiconductor element including a first main electrode placed on the one surface and a second main electrode placed on the back surface; a first heat dissipation member and a second heat dissipation member placed to sandwich the semiconductor element, the first heat dissipation member placed close to the one surface and connected to the first main electrode, the second heat dissipation member placed close to the back surface; and a lead frame including at least one first main terminal electrically connected to the first heat dissipation member and a second main terminal connected to the second main electrode.

The second main terminal includes a connection portion, a facing portion, and at least one non-facing portion. The connection portion is connected with the second main electrode. The facing portion extends from the connection portion, has a first end continuous from the connection portion and a second end continuous from the at least one non-facing portion, and faces the first heat dissipation member. The at least one non-facing portion and the at least one first main terminal are arranged in a direction orthogonal to the thickness direction. The second heat dissipation member is connected to the semiconductor element via the second main terminal. In the lead frame, the at least one first main terminal includes multiple first main terminals or the at least one non-facing portion of the second main terminal includes multiple non-facing portions. The at least one first main terminal and the at least one non-facing portion of the second main terminal are alternately arranged in such a manner that a side surface of one of the at least one first main terminal faces a side surface of adjacent one of the at least one non-facing portion of the second main terminal to form multiple pairs of the side surfaces that face each other.

In the semiconductor device according to the above aspect, the first main terminal and the second main terminal are provided as members different from the first heat dissipation member and the second heat dissipation member. The second main terminal is placed between the second heat dissipation member and the semiconductor element, and is connected to the second electrode. As the portion that faces and has the same potential as that of the second main electrode, the facing portion of the second main terminal is closest. The first main terminal and the non-facing portion of the second main terminal are alternately placed so that the side surfaces face each other. Multiple pairs of side surfaces of the first main terminal and the non-facing portion of the second main terminal are formed. As the result, it is possible to provide the semiconductor device capable of reducing the inductance.

Hereinafter, multiple embodiments will be described with reference to the drawings. In the embodiments, functionally and/or structurally corresponding parts are denoted by the same reference numerals. In the following description, a thickness direction of a semiconductor element is shown as a Z direction and a direction orthogonal to the Z direction is shown as an X direction. A direction orthogonal to both of the Z direction and the X direction is shown as a Y direction. Unless otherwise specified, a shape along an XY plane defined by the X direction and the Y direction is a planar shape.

First Embodiment

First, an electric power conversion device including a semiconductor device will be described with reference to FIG. **1**.

<Schematic Configuration of Electric Power Conversion Device>

An electric power conversion device **1** shown in FIG. **1** is mounted on, for example, an electric vehicle or a hybrid vehicle. The electric power conversion device **1** converts a DC voltage supplied from a DC (direct current) power source **2** mounted on the vehicle into three-phase AC and outputs it to a three-phase AC type motor **3**. The motor **3** functions as a travel driving source of the vehicle. The electric power conversion device **1** can also convert an electric power generated by the motor **3** into a DC and charge the DC power source **2**. The motor **3** having a power generation function may be referred to as a motor generator. The electric power conversion device **1** is capable of bidirectional power conversion.

The electric power conversion device **1** includes a smoothing capacitor **4** and an inverter **5** as a power converter. A positive electrode terminal of the smoothing capacitor **4** is connected to a positive electrode of the DC power source **2**, which is a high potential side electrode of the DC power source **2**. A negative electrode terminal of the smoothing capacitor **4** is connected to a negative electrode of the DC power source **2**, which is a low potential side electrode of the DC power source **2**. The inverter **5** converts the input DC electric power into a three-phase AC having a predetermined frequency, and outputs the three-phase AC to the motor **3**. The inverter **5** converts the AC electric power generated by the motor **3** into the DC electric power. The inverter **5** corresponds to a DC-AC converter.

The inverter **5** includes upper-lower arm circuits **6** for three phases. In the upper-lower arm circuit **6** of each phase, two arms are connected in series between a high potential power source line **7** and a low potential power source line **8**. The high potential power source line **7** is a power source line on a positive electrode side, and the low potential power source line **8** is a power source line on a negative electrode side. In the upper-lower arm circuit **6** of each phase, a connection point between the upper arm and the lower arm is connected to an output line **9** to the motor **3**.

In this embodiment, an n-channel type insulated gate bipolar transistor **6*i*** (hereinafter referred to as an IGBT **6*i***) is adopted as a switching element constituting each arm. FWDs **6*d*** as freewheel diodes are connected in reverse parallel to each IGBT **61**. The upper-lower arm circuits **6** for one phase are configured to have two IGBTs **6*i***. In the upper arm, collector electrodes of the IGBTs **6*i*** are electrically connected to the high potential power source line **7**. In the lower arm, emitter electrodes of the IGBTs **6*i*** are electrically connected to the low potential power source line **8**. The emitter electrodes of the IGBTs **6*i*** in the upper arm and the collector electrodes of the IGBTs **6*i*** in the lower arm are connected to each other.

In addition to the smoothing capacitor **4** and the inverter **5** described above, the electric power conversion device **1** may include a converter which is a power converter different from the inverter **5**, a drive circuit for the switching element constituting the inverter **5** and the converter, and the like. The converter is a DC-DC converter that converts a DC voltage into the DC voltage having a different value.

<Semiconductor Device>

As shown in FIGS. **2** to **9**, a semiconductor device **20** includes a sealing resin body **30**, a semiconductor element **40**, a heat sink **50**, and a lead frame **60** including a main terminal **61** and a signal terminal **67**. FIG. **3** shows elements in the sealing resin body **30** of FIG. **2**. In FIG. **5**, for convenience, the sealing resin body **30** is omitted. FIG. **8** shows a connection state of the lead frame **60**, specifically, a connection state between the semiconductor element **40** and a heat sink **50**C. FIG. **9** shows a positional relationship between each heat sink **50** and the lead frame **60**. FIG. **8** and FIG. **9** show the lead frame **60** before a tie bar is cut.

The sealing resin body **30** seals a part of other elements constituting the semiconductor device **20**. The other elements are exposed to the outside of the sealing resin body **30**. The sealing resin body **30** seals, for example, the semiconductor element **40**. The sealing resin body **30** seals a connection portion formed between other elements constituting the semiconductor device **20**. The sealing resin body **30** seals the connection portion between the semiconductor element **40** and the lead frame **60**. The sealing resin body **30** seals the connection portion between the heat sink **50** and the lead frame **60**. The sealing resin body **30** may be referred to as a mold resin.

The sealing resin body **30** is made of, for example, an epoxy resin. The sealing resin body **30** is formed by, for example, a transfer molding method. As shown in FIG. **2**, FIG. **3**, and FIG. **4**, the sealing resin body **30** has one surface

300 and a back surface **301** opposite to the one surface **300** in the Z direction. The one surface **300** and the back surface **301** are, for example, flat surfaces. The sealing resin body **30** has a lateral surface connecting the one surface **300** and the back surface **301**. In the present embodiment, the sealing resin body **30** has a substantially rectangular shape in a plan view. The sealing resin body **30** has a side surface **302** from which the main terminal **61** protrudes to the outside and a side surface **303** from which the signal terminal **67** protrudes to the outside. The side surface **303** is a surface opposite to the side surface **302** in the Y direction.

In the semiconductor element **40**, the element is formed on a semiconductor substrate such as Si, SiC, or GaN. The semiconductor device **20** includes at least one semiconductor element **40**. In the present embodiment, the IGBT **6***i* and FWD **6***d* are formed on the semiconductor substrate constituting the semiconductor element **40**. As described above, RC (Reverse Conducting)-IGBT is adopted as the semiconductor element **40**. The semiconductor element **40** constitutes one of the above-described arms. The semiconductor element **40** is sometimes referred to as a semiconductor chip.

The semiconductor element **40** has a vertical structure so that the main current flows in the Z direction. Although not shown, the semiconductor element **40** has a gate electrode. The gate electrode has, for example, a trench structure. As shown in FIGS. **6** and **7**, the semiconductor element **40** has main electrodes **41** on both sides thereof in the thickness direction, that is, in the Z direction. A main current flows between the main electrodes **41**. Specifically, as the main electrodes **41**, a collector electrode **41**C is provided on one surface side, and an emitter electrode **41**E is provided on the back surface side, which is the opposite surface to the one surface side. The collector electrode **41**C also serves as a cathode electrode of the FWD **6***d*, and the emitter electrode **41**E also serves as an anode electrode of the FWD **6***d*. The collector electrode **41**C is formed on almost the entire surface of the one side. The emitter electrode **41**E is formed on a part of the back surface. The collector electrode **41**C corresponds to a first main electrode, and the emitter electrode **41**E corresponds to a second main electrode.

As shown in FIG. **3** and FIG. **6**, the semiconductor element **40** has a pad **42**, which is an electrode for signals, on the forming surface of the emitter electrode **41**E. The pad **42** is formed at a position different from that of the emitter electrode **41**E. The pad **42** is electrically isolated from the emitter electrode **41**E. The semiconductor element **40** has a substantially rectangular shape in a plane. The pad **42** is formed at an end on the side opposite to the formation region of the emitter electrode **41**E in the Y direction.

The semiconductor element **40** has, for example, five pads **42**. Specifically, the pad **42** has a gate electrode pad, a potential detection pad of the emitter electrode **41**E, a current sense pad, and a temperature detection pad of the semiconductor element **40**. The pad **42** for temperature detection includes an anode potential pad of a temperature sensing diode, which is a temperature detecting element, and a cathode potential pad. The five pads **42** are formed side by side in the X direction.

An Al-based material can be used as the configuration material of the electrode such as the main electrode **41** and the pad **42**. When jointing by solder or the like, it may be preferable to include Cu as a material. For example, AlCuSi can be used.

The heat sink **50** is the heat dissipation member placed so as to sandwich the semiconductor element **40** in the Z direction. The heat sink **50** functions to radiate (dissipate) the heat generated by the semiconductor element **40**. A pair of the heat sinks **50** are placed so as to sandwich the semiconductor element **40** in the Z direction. The semiconductor device **20** has, as the pair of heat sinks **50**, the heat sink **50**C placed close to the collector electrode **41**C and a heat sink **50**E placed close to the emitter electrode **41**E. The heat sink **50**C corresponds to a first heat dissipation member, and the heat sink **50**E corresponds to a second heat dissipation member.

The heat sinks **50**C and **50**E are provided so as to accommodate the semiconductor element **40** inside in a plan view from the Z direction. The heat sink **50**C has a mounting surface **500**C close to the semiconductor element **40** and a heat dissipation surface **501**C opposite to the mounting surface **500**C in the Z direction. The heat sink **50**E has a mounting surface **500**E close to the semiconductor element **40** and a heat dissipation surface **501**E opposite to a mounting surface **500**E in the Z direction. The mounting surfaces **500**C and **500**E face each other in the Z direction. The mounting surfaces **500**C and **500**E are substantially parallel to each other. The mounting surface **500**C corresponds to a facing surface of the first heat dissipation member.

In the present embodiment, the heat sinks **50**C and **50**E have a substantially rectangular shape in a plan view. The lengths of the heat sinks **50**C and **50**E in the X direction are substantially same. The length of the heat sink **50**C in the Y direction is longer than that of the heat sink **50**E. As shown in FIG. **3**, FIG. **5**, and FIG. **6**, the heat sink **50**C straddles the heat sink **50**E in the Y direction. The heat sink **50**C has an overlapping portion **51**C and a non-overlapping portion **52**C. The overlapping portion **51**C is a portion overlapping with the heat sink **50**E in the plan view from the Z direction. The overlapping portion **51**C is an area facing the mounting surface **500**E of the heat sink **50**E in the Z direction. The non-overlapping portion **52**C is continuous from the overlapping portion **51**C at a position close to the main terminal **61** in the Y direction. The non-overlapping portion **52**C is a portion that does not overlap with the heat sink **50**E.

The collector electrode **41**C is connected to the mounting surface **500**C of the heat sink **50**C via a bonding member **80**. The collector electrode **41**C is connected to the overlapping portion **51**C of the heat sink **50**C. The heat sink **50**C is connected to the main terminal **61** (main terminal **61**C) corresponding to the collector electrode **41**C. The main terminal **61**C is connected to the non-overlapping portion **52**C of the heat sink **50**C. The main terminal **61**C is electrically connected to the collector electrode **41**C via the heat sink **50**C. The heat sink **50**C functions as a wiring connecting the collector electrode **41**C and the main terminal **61**C.

The mounting surface **500**E of the heat sink **50**E is connected to the main terminal **61** (main terminal **61**E) corresponding to the emitter electrode **41**E via a joint member **81**. The main terminal **61**E is connected to the emitter electrode **41**E via a joint member **82**. The heat sink **50**E is connected to the emitter electrode **41**E via the joint members **81** and **82** and the main terminal **61**E. The main terminal **61**E is electrically connected to the emitter electrode **41**E via no heat sink **50**E.

At least a part of each of the heat sinks **50**C and **50**E is sealed by the sealing resin body **30**. In this embodiment, the heat dissipation surface **501**C of the heat sink **50**C is exposed from the sealing resin body **30**. The heat dissipation surface **501**C is substantially flush with the one surface **300**. The portion of the surface of the heat sink **50**C other than the connection portion with the collector electrode **41**C, the heat dissipation surface **501**C, and the connection portion with the main terminal **61**C is covered with the sealing resin body

30. Similarly, the heat dissipation surface **501**E of the heat sink **50**E is exposed from the sealing resin body **30**. The heat dissipation surface **501**E is substantially flush with the back surface **301**. The portion of the surface of the heat sink **50**E other than the connection portion with the main terminal **61**E and the heat dissipation surface **501**E is covered with the sealing resin body **30**.

As the heat sink **50**, for example, a metal plate or a composite material of a metal body and an insulator can be used. The composite material is, for example, a DBC (Direct Bonded Copper) substrate. The same type of materials may be used for the heat sink **50**C and the heat sink **50**E, or different materials may be used. In this embodiment, as shown in FIG. **3**, FIG. **6**, FIG. **7** and the like, DBC substrates are used as the heat sinks **50**C and **50**E.

The heat sink **50** has an insulator **50***x* and metal bodies **50***y* and **50***z* arranged so as to sandwich the insulator **50***x*. The insulator **50***x* is a ceramic substrate. The metal bodies **50***y* and **50***z* are formed by material including, for example, Cu. The metal bodies **50***y* and **50***z* are directly bonded to the insulator **50***x*. The heat sink **50** is stacked in the order of the metal body **50***y*, the insulator **50***x*, and the metal body **50***z* from the side of the semiconductor element **40**. The heat sink **50** has a three-layer structure.

The planar shapes and sizes of the metal bodies **50***y* and **50***z* are substantially same as each other. The planar shape of the insulator **50***x*, which is the intermediate layer, is similar to that of the metal bodies **50***y* and **50***z*. The size of the insulator **50***c* is larger than that of the metal bodies **50***y* and **50***z*. The insulator **50***x* extends to the outside of the metal bodies **50***y* and **50***z* all around. In the heat sinks **50**C and **50**E, one surface of the metal body **50***y* forms the mounting surfaces **500**C and **500**E. In the heat sinks **50**C and **50**E, one surface of the metal body **50***z* forms the heat dissipation surfaces **501**C and **501**E.

The lead frame **60** includes an external connection terminal. The external connection terminal electrically connects the above-described arm to the outside of the semiconductor device **20**. The outside of the semiconductor device **20** is, for example, another semiconductor device **20**, the smoothing capacitor **4**, or the like. The lead frame **60** includes, as the external connection terminal, the main terminal **61** and the signal terminal **67**. The lead frame **60** is configured as a member different from the heat sink **50**. The lead frame **60** is placed between the heat sinks **50**C and **50**E in the Z direction. The lead frame **60** is formed by processing a metal plate made of Cu or the like by a press or the like.

The main terminal **61** is an external connection terminal through which the main current flows. The lead frame **60** is provided with multiple main terminals **61**. The main terminal **61** is electrically connected to the corresponding main electrode **41**. The semiconductor device **20** has, as the main terminals **61**, the main terminal **61**C electrically connected to the collector electrode **41**C and the main terminal **61**E electrically connected to the emitter electrode **41**E. The main terminal **610** corresponds to a first main terminal, and the main terminal **61**E corresponds to a second main terminal. The main terminal **61**C may be also referred to as a collector terminal. The main terminal **61**E may be also referred to as an emitter terminal.

An electrical connection portion with the main electrode **41** in the main terminal **61** is sealed by the sealing resin body **30**. Each of the main terminals **61** extends from the electrical connection portion with the main electrode **41** in the Y direction and extends away from the semiconductor element **40**. All the main terminals **61** project outward from the side surface **302** of the sealing resin body **30**.

As shown in FIG. **3**, FIG. **5**, and FIG. **7**, the main terminal **61**C has a connection portion **62**C and an extension portion **63**C. The connection portion **62**C is a connection portion of the main terminal **61**C to the heat sink **50**C. The main terminal **61**C may be connected to the heat sink **50**C via a connection member such as solder. The main terminal **61**C is directly connected to the heat sink **50**C by ultrasonic bonding, friction stir welding, laser welding or the like. The extension portion **63**C is a portion extending from the connection portion **62**C. The extension portion **63**C is integrally connected to the connection portion **62**C.

As shown in FIG. **3**, FIG. **5**, and FIG. **6**, the main terminal **61**E has a connection portion **62**E and an extension portion **63**E. The connection portion **62**E is a connection portion of the main terminal **61**E to the emitter electrode **41**E. As described above, the connection portion **62**E of the main terminal **61**E is connected to the emitter electrode **41**E via the joint member **82**. The connection portion **62**E is a portion overlapping with the emitter electrode **41**E in the plan view from the Z direction. The main terminal **61**E is connected to the heat sink **50**E including the connection portion **62**E. The joint member **81** is placed on one surface of the connection portion **62**E, and the joint member **82** is placed on a surface opposite to the one surface. In the plan view from the Z direction, at least a part of the joint members **81** and **82** overlap each other.

The extension portion **63**E is a portion extending from the connection portion **62**E. The extension portion **63**E is integrally connected to the connection portion **62**E. The extension portion **63**C has a facing portion **64**E and a non-facing portion **65**E. The facing portion **64**E is a portion facing the heat sink **50**C. The facing portion **64**E faces the mounting surface **500**C of the heat sink **50**C in the Z direction. One end of the facing portion **64**E is connected to the connection portion **62**E, and the other end is connected to the non-facing portion **65**E.

The non-facing portion **65**E faces a portion facing the heat sink **50**C. The non-facing portion **65**E extends from the facing portion **64**E and extends away from the semiconductor element **40**. The non-facing portion **65**E and the extension portion **63**C of the main terminal **61**C are arranged in one direction orthogonal to the Z direction. The extension portion **63**C of the main terminal **61**C and the non-facing portion **65**E of the main terminal **61**E are placed so that side surfaces **610**C and **610**E face each other. A part of the extension portion **63**C and a part of the non-facing portion **65**E are provided as a connection portion with the outside. The extension portion **63**C and the non-facing portion **65**E may be also referred to as a terminal portion. At least, the number of main terminals **61**C in the lead frame **60** or the number of non-facing portions **65**E in the lead frame **60** is two or more.

The main terminal **61**C and the non-facing portion **65**E are alternately placed in the arrangement direction. The alternate arrangement is arrangement in which the main terminal **61**C and the main terminal **61**E are adjacent to each other in the arrangement direction. The plate surfaces of the main terminal **61**C and the non-facing portion **65**E do not face each other, and the side surfaces **610**C and **610**E face each other. Due to the alternate arrangement, the lead frame **60** has multiple sets of facing side surfaces **610**C and **610**E. At least a part of the side surfaces **610**C and **610**E may face each other in the plate thickness direction of the main terminal **61**. For example, the side surfaces may be placed so as to shift in the plate thickness direction. Preferably, one of side surfaces **710**C and **710**E facing each other is placed to face the other one over the entire area in the thickness direction.

The minimum alternate configuration is a combination of two main terminals **61**C and one non-facing portion **65**E or a combination of one main terminal **61**C and two non-facing portions **65**E. For example, in the case of two main terminals **61**C and one non-facing portion **65**E, in the arrangement direction, the main terminal **61**C, the non-facing portion **65**E, and the main terminal **61**C are placed in this order. Two sets of side surfaces **610**C and **610**E facing each other are formed.

In the present embodiment, the lead frame **60** includes four main terminals **61**C and five non-facing portions **65**E. The plate thickness of the lead frame **60** is made substantially uniform over the entire area. The multiple main terminals **61**C have substantially the same structure as each other. The connection portion **62**C of the main terminal **61**C is ultrasonically bonded to the non-overlapping portion **52**C of the mounting surface **500**C of the heat sink **50**C. The connection portion **62**C is connected to the metal body **50***y* constituting the heat sink **50**C. The connection portion **62**C is connected to the mounting surface **500**C near the one end in the Y direction.

The extension portion **63**C extends along the Y direction in the plan view in Z direction. That is, the main terminal **61**C extends along the Y direction in the same plan view. The main terminal **61**C extends with a substantially constant width. The extension portion **63**C has a bent portion. The extension portion **63**C projects from the sealing resin body **30** at a position closer to the mounting surface **500**E than the connection portion **62**C in the Z direction. The main terminal **61**C has a crank shape in the YZ plane.

The main terminal **61**E has only one connection portion **62**E. The main terminal **61**E has a common connection portion **62**E integrally provided with multiple non-facing portions **65**E. The lead frame **60** has five extension portions **63**E. Each extension portion **63**E in the non-facing portion **65**E extends from one common connection portion **62**E. In the extension portion **63**E, a plate surface extending in substantially parallel to the mounting surfaces **500**C and **500**E faces the mounting surfaces **500**C and **500**E. Multiple facing portions **64**E are arranged in the X direction while being separated from each other. The facing portion **64**E extends while having a predetermined gap with the mounting surface **500**E of the heat sink **50**E. The sealing resin body **30** is interposed between the facing portion **64**E and the mounting surface **500**E.

The multiple non-facing portions **65**E have the substantially same structure. The non-facing portion **65**E extends with a substantially constant width in the Y direction. The width of the non-facing portion **65**E is almost the same as the width of the main terminal **61**E. The non-facing portion **65**E and the main terminal **61** are alternately placed in the X direction. The non-facing portions **65**E are placed at both ends in the arrangement direction. The main terminal **61**C and the non-facing portion **65**E are placed at substantially the same positions in the Z direction and located closer to the tip side than to the bent portion of the main terminal **61**C. Almost the entire surfaces of the side surfaces **610**C and **610**E face each other. As shown in FIG. **4**, the lead frame **60** has eight sets of side surfaces **610**C and **610**E facing each other. The facing distance of the side surfaces **610**C and **610**E, in other words, a pitch with the main terminal **61** and the non-facing portion **65**E (second main terminal **61**E) is constant.

As shown in FIG. **8**, the main terminals **61**C and **61**E are arranged line-symmetrically with respect to the center line CL passing through the element center of the semiconductor element **40** in the X direction. The element center is the center of the semiconductor element **40** when there is one semiconductor element **40** as in the present embodiment. When there are two semiconductor elements **40**, for example, it is the central position between the centers in the alignment direction of the two semiconductor elements **40**. The center line CL is a virtual line orthogonal to the X direction and passing through the element center.

The signal terminal **67** is electrically connected to the pad **42** of the corresponding semiconductor element **40**. The lead frame **60** has multiple signal terminals **67**. The signal terminal **67** is connected to the pad **42** inside the sealing resin body **30**. The five signal terminals **67** connected to the pads **42** extend in the Y direction away from the semiconductor element **40**, respectively. The signal terminals **67** are arranged in the X direction. All the signal terminals **67** project outward from the side surface **303** of the sealing resin body **30**.

In this embodiment, as shown in FIG. **6**, the signal terminal **67** is connected to the pad **42** via a joint member **83**. As the above joint members **80**, **81**, **82**, and **83**, a conductive paste including solder, Ag, or the like can be used. In this embodiment, solder is used as the joint members **80**, **81**, **82**, and **83**.

The lead frame **60** has a suspension lead **68**. The lead frame **60** shown in FIG. **8** and FIG. **9** has an outer peripheral frame **69** and tie bars **70** and **71** before the tie bar cut. The outer peripheral frame **69** may be also referred to as an outer peripheral frame body. The tie bar **70** extends in the X direction, and the both ends are connected to the outer peripheral frame **69**. The multiple signal terminals **67** are supported by the outer peripheral frame **69** with use of the tie bar **70**. One end of the suspension lead **68** is connected to the connection portion **62**E, and the other end is connected to the tie bar **70**. Two suspension leads **68** are placed so as to sandwich the signal terminal **67** in the X direction.

The tie bar is placed on the opposite side to the tie bar **70** with respect to the semiconductor element **40** so that the semiconductor element **40** is paced between the tie bar **71** and the tie bar **70** in the Y direction. The tie bar **71** extends in the X direction, and the both ends are connected to the outer peripheral frame **69**. The multiple main terminals **61**C are supported by the outer peripheral frame **69** with use of the tie bar **71**. The tie bar **71** is connected to the extension portion **63**C. The non-facing portions **65**E are supported by the outer peripheral frame **69** with use of the tie bar **71**. The tips of the extension portions **63**C and **63**E of the main terminals **61**C and **61**E are connected to the outer peripheral frame **69** in the Y direction. The connection portion **62**E is connected to the tie bar **70** via the suspension lead **68**, and connected to the tie bar **71** via the extension portion **63**E.

After the molding of the sealing resin body **30**, the unnecessary portion of the lead frame **60** such as the outer peripheral frame **69** and the tie bars **70** and **71** are removed. Thereby, in the semiconductor device **20**, the main terminals **61**C and **61**E are electrically separated. Further, the multiple signal terminals **67** are electrically separated. The semiconductor device **20** does not include, as the lead frame **60**, the outer peripheral frame **69** and the tie bars **70** and **71**, and includes the main terminal **61**, the signal terminal **67**, and the suspension lead **68**.

In the semiconductor device **10** configured as described above, the sealing resin body **30** integrally seals the semiconductor element **40** and a part of each of the heat sinks **50**, a part of each of the main terminals **61**, and a part of the signal terminals **67**. That is, elements configuring one arm are sealed. Such a semiconductor device **20** may be referred to as a one-in-one package.

The heat dissipation surface **501**C of the heat sink **50**C is substantially flush with the one surface **300** of the sealing resin body **30**. The heat dissipation surface **501**E of the heat sink **50**E is substantially flush with the back surface **301** of the sealing resin body **30**. The semiconductor device **20** has a double-sided heat dissipation structure in which the heat dissipation surfaces **501**C and **501**E are both exposed from the sealing resin body **30**. The semiconductor device **20** can be formed, for example, by cutting the heat sinks **50** together with the sealing resin body **30**. Further, the sealing resin body **30** may be molded with the heat dissipation surfaces **501**C and **501**E in contact with the cavity wall surface of the mold for molding the sealing resin body **30**.

Overview of First Embodiment

FIG. **10** is a comparative example of a semiconductor device. In the comparative example, the related elements are denoted by adding “r” to the tails of the reference numerals in the present embodiment. As shown in FIG. **10**, a semiconductor device **20***r* of the comparative example includes a bonding wire **85***r* and a terminal **90***r*. A signal terminal **67***r* is connected to a pad (not shown) of a semiconductor element **40***r* via the bonding wire **85***r*. The terminal **90***r* is interposed between an emitter electrode (not shown) of the semiconductor element **40***r* and a heat sink **50**Er. The terminal **90***r* functions as a spacer for securing the height of the bonding wire **85***r*.

The heat sink **50**Er is thermally and electrically connected to the emitter electrode via the terminal **90***r*. The main terminal **61**E is connected to the heat sink **50**Er. The main terminal **61**Er is connected to the heat sink **50**Er, for example. The heat sink **50**Er has a function of dissipating heat generated by the semiconductor element **40**, and a function of wiring that connects the emitter electrode and the main terminal **61**Er.

In such a configuration, as the same potential portion as the emitter electrode, mainly, the heat sink **50**Er faces the heat sink **50**Cr having the same potential as the collector electrode. A mounting surface **500**Er of the heat sink **50**Er faces most of the mounting surface **500**Cr of the heat sink **50**Cr. As shown by a broken line arrow in FIG. **10**, the direction of the main current is substantially opposite in the heat sinks **50**Cr and **50**Er. As a result, the magnetic fluxes generated when the main current flows cancel each other, and the inductance can be reduced. A facing distance Dr contributing to the reduction of the inductance is a distance between the mounting surfaces **500**Cr and **500**Er.

On the other hand, in the present embodiment, the lead frame **60** including the main terminal **61** is provided as a member separate from the heat sink **50**. The main terminal **61**E is placed between the heat sink **50**E and the semiconductor element **40**, and is connected to the emitter electrode **41**E. Thereby, as shown in FIG. **6**, as the portion having the same potential as the emitter electrode **41**E facing the heat sink **50**C, the facing portion **64**E of the main terminal **61**E is closest. As the portion having the same potential as the emitter electrode, mainly, the main terminal **61**E faces the heat sink **50**C. A facing distance D1 between the facing portion **64**E and the mounting surface **500**C of the heat sink **50**C is shorter than the above facing distance Dr. Thereby, it is possible to enhance the effect of canceling the magnetic flux as compared with the comparative example. As the result, as shown in FIG. **11**, it is possible to further reduce the inductance as compared with the comparative example. FIG. **11** shows results obtained by magnetic field analysis (simulation) of the inductances of the heat sink **50**C (**50**Cr) and the facing portion on the emitter potential side.

Further, the main terminal **610** (extension portion **63**C) and the non-facing portion **65**E of the main terminal **61**E are alternately placed. The side surfaces **610**C and **610**E of the adjacent main terminal **61**C and the adjacent non-facing portion **65**E face each other. At the main terminal **61**C and the non-facing portion **65**E, the directions of the main currents are substantially opposite. Thereby, the magnetic fluxes generated when the main current flows cancel each other, and the inductance can be reduced. However, the side surface is smaller than the plate surface. Therefore, the lead frame **60** has multiple sets of facing side surfaces **610**C and **610**E. Accordingly, it is possible to effectively reduce the inductance. Further, multiple main terminal **61**C and non-facing portions **65**E of the same type are provided in parallel. This also makes it possible to reduce the inductance.

As described above, according to the semiconductor device **20** of the present embodiment, it is possible to reduce the inductance.

FIG. **12** is a diagram showing an effect due to multiple sets of facing side surfaces **610**C and **610**E. FIG. **12** is a magnetic field analysis result showing a relationship between the total number of terminal portions of the main terminals **61** and the inductance. The terminal portion is, as described above, a portion provided as connection, in the main terminal **61**, with the outside. The lead frame **60** includes, as the terminal portion, the extension portion **63**C of the main terminal **61**C and the non-facing portion **65**E of the main terminal **61**E.

The reference is a configuration including two terminal portions, that is, one main terminal **61**C and one non-facing portion **65**E. As shown in FIG. **12**, when the total number of terminal portions is three or more, it is possible to further reduce the inductance as compared with a configuration where the total number is two. In the present embodiment, since, at least, either the number of main terminals **61**C or the number of non-facing portions **65**E is two or more, it is possible to reduce the inductance. Further, it is clear that the inductance can be reduced as the number of terminal portions is increased. In the present embodiment, four main terminals **61**C and five non-facing portions **65**E of the main terminals **61**E are provided. Accordingly, it is possible to effectively reduce the inductance.

The configuration of the main terminal **61** is not limited to the example having four main terminals **61**C and five non-facing portions **65**E of the main terminals **61**E. The number of main terminals **61**C may be larger than the number of the main terminals **61**E (non-facing portions **65**E). For example, the number of main terminals **61**C may be five, and the number of non-facing portions **65**E may be four. In this case, the main terminals **61**C are arranged at both ends in the alignment direction. The total number of terminal portions is not limited to an odd number. It may be an even number. In a modification shown in FIG. **13**, there are three main terminals **61**C and three non-facing portions **65**E, for a total of six.

The main terminal **61**E may include multiple connection portions **62**E. For example, when the number of connection portions **62**E and the number of non-facing portions **65**E are same, the main terminal **61**E has an independent structure one by one, similarly to the main terminal **61**C. In a modification shown in FIG. **14**, the main terminal **61**E includes four non-facing portions **65**E. The main terminal **61**E includes two connection portions **62**E, and two extension portions **63**E extend from each connection portion **62**E. The two connection portions **62**E are arranged in the X direction, and, in this arrangement state, are connected to the emitter electrode **41**E of the semiconductor element **40**.

On the other hand, the main terminal **61**E includes one connection portion **62**E. Since the number of connection portions **62**E is one, the emitter electrode **41**E of the semiconductor element **40** is easily positioned. When one connection portion **62**E is positioned, all the facing portions **64**E have the desired positional relationship with respect to the heat sink **50**C. Thereby, it is possible to effectively reduce the inductance. Further, as compared with the configuration in which the connection portion **62**E is divided in multiple portions, it is possible to reduce the heat resistance in a heat transfer path from the emitter electrode **41**E to the heat sink **50**E. Furthermore, it is possible to improve the productivity.

The connection portion **62**E of the lead frame **60** may be subjected to a treatment for improving wettability, such as Au plating. For example, by applying Au plating to a surface close to the semiconductor element **40**, the semiconductor element **40** is self-aligned with respect to the lead frame **60**. Thereby, it is possible to simplify the manufacturing process.

Although not shown, the signal terminal **67** may be electrically connected to the pad **42** of the semiconductor element **40** via a bonding wire. In this case, by making the plate thickness of the lead frame **60** thick, the height of the bonding wire is increased. However, since the facing portion **64**E is close to the mounting surface **500**C of the heat sink **50**C, it is possible to further reduce the inductance as compared with the above comparative example.

On the other hand, in this embodiment, the signal terminal **67** is connected to the pad **42** via a joint member **83**. The semiconductor device **20** has a bondingless structure. It is not necessary to secure the height of the bonding wire between the semiconductor element **40** and the heat sink **50**E. Since the lead frame **60** is thin, the distance from the emitter electrode **41**E to the heat sink **50**E can be shortened as compared with the comparative example. Accordingly, as shown in FIG. **15**, it is possible to reduce the heat resistance as compared with the comparative example. That is, it is possible to improve the heat dissipation.

Since the lead frame **60** is thin, as shown in FIG. **6**, a facing distance D2 between the mounting surfaces **500**C and **500**E is shorter than the facing distance Dr of the reference example. Accordingly, the size of the semiconductor device **20** can be reduced in the Z direction. Further, since the bonding wire is not necessary, the joint members **80**, **81**, **82**, and **83** can be reflowed all at once. Thereby, it is possible to simplify the manufacturing process. FIG. **15** shows a result of thermal analysis (simulation).

The connection position of the main terminal **61**C with respect to the heat sink **50**C is not particularly limited. For example, the main terminal **61**C may be connected to the side surface of the heat sink **50**C. In the present embodiment, the heat sink **50**C is longer than the heat sink **50**E in the Y direction. Thereby, the heat sink **50**C includes the overlapping portion **51**C and the non-overlapping portion **52**C. The connection portion **62**C of the main terminal **61**C is connected to the non-overlapping portion **52**C of the mounting surface **500**C of the heat sink **50**C. Accordingly, after the reflow, the main terminal **61**C can be connected to the heat sink **50**C. The connection method that does not use the joint member such as solder can be employed. It is possible to prevent the occurrence of the electromigration.

In the present embodiment, the main terminals **61**C and **61**E are placed line-symmetrically with respect to the center line CL of the semiconductor element **40** in the X direction. Thereby, the main current flows so as to be line-symmetric with respect to the center line CL. The main current flows almost evenly on the left side and the right side with respect to the center line CL. Thereby, it may be possible to reduce the inductance. In addition, it may be possible to suppress local heat generation.

Second Embodiment

This embodiment is a modification of a basic aspect of the preceding embodiment. In the above embodiment, the facing portion **64**E of the main terminal **61**E is completely separated for each non-facing portion **65**E. Instead of this, at least a part of the facing portion **64**E may be integrated by multiple non-facing portions **65**E.

FIG. **16** is a diagram showing the semiconductor device **20** of the present embodiment, and corresponds to FIG. **5**. Similarly to FIG. **5**, for convenience, the sealing resin body **30** is omitted. The main terminal **61**E includes, as the facing portion **64**E, a common portion **640**E and a branch portion **641**E. The main terminal **61**E includes one connection portion **62**E similarly to the preceding embodiment. The common portion **640**E is connected to the connection portion **62**E. The common portion **640**E is placed at a root portion close to the connection portion **62**E in the extension portion **63**E. In the extending direction of the extension portion **63**E, a portion within a predetermined area from the connection portion **62**E is defined as the common portion **640**E.

The common portion **640**E is shared by multiple non-facing portions **65**E. The common portion **640**E extends form the connection portion **62**E in the Y direction without being divided into the multiple portions. The common portion **640**E is provided so as not to interfere the connection between the main terminal **61**C and the heat sink **50**C. Similarly to the preceding embodiment, the connection portion **62**C is connected to the non-overlapping portion **52**C that is the mounting surface **500**C of the heat sink **50**C. The common portion **640**E is placed within a range overlapping with the heat sink **50**E in the plan view from the Z direction. The common portion **640**E faces the overlapping portion **51**C of the heat sink **50**C.

The branch portions **641**E are portions branched from the common portion **640**E. The branch portions **641**E connects the common portion **640**E and the non-facing portion **65**E. The number of branch portions **641**E is same as the number of non-facing portions **65**E. The branch portion **641**E extends along the Y direction integrally with the corresponding non-facing portion **65**E. The branch portion **641**E faces, at least, the non-overlapping portion **52**C of the heat sink **50**C.

Overview of Second Embodiment

In the present embodiment, the main terminal **61**E includes, as the facing portion **64**E, the common portion **640**E. Accordingly, as described in the preceding embodiment, as compared with the configuration that does not include the common portion **640**E, the area along the XY plane of the main terminal **61**E is expanded. Thereby, the areas facing the heat sink **50**C and the main terminal **61**E are increased, and it is possible to reduce the inductance.

Further, it is possible to reduce the heat resistance. Thereby, it is possible to improve the heat dissipation.

The common portion **640**E may be placed as a part of the facing portion **64**E in the extending direction of the extension portion **63**E. For example, the common portion **640**E may be placed at a portion away from the connection portion **62**E. In the present embodiment, the common portion **640**E is connected to the connection portion **62**E. That is, the area of the main terminal **61**E is expanded in the vicinity of the emitter electrode **41**E. Thereby, it is possible to further improve the heat dissipation.

Third Embodiment

This embodiment is a modification of a basic aspect of the preceding embodiment. In the above embodiment, the thickness of the lead frame **60** is substantially constant over the entire area. Instead of this, the thickness of the lead frame **60** may be partially different. A modified lead frame **60** may be used.

FIG. **17** is a cross-sectional view showing a periphery of the semiconductor element **40** in the semiconductor device **20** of the present embodiment. In FIG. **17**, for convenience, the sealing resin body **30**, the main electrode **41**, and the pad are omitted. As shown in FIG. **17**, in the lead frame **60**, the signal terminal **67** is thinner than the main terminal **61**E. A facing distance D3 between the signal terminal **67** and the mounting surface **500**C of the heat sink **50**C is longer than the facing distance D**1** between the main terminal **61**E and the mounting surface **500**C. In the lead frame **60**, the signal terminal **67** is a thin portion, and the other is a thick portion. In the signal terminal **67**, the plate surface close to the heat sink **50**E is substantially flush with the main terminal **61**E.

Overview of Third Embodiment

In the present embodiment, the signal terminal **67** of the lead frame **60** is locally thinned. Thereby, it is possible to secure the electrical insulation between the heat sink **50**C connected to the collector electrode **41**C and the signal terminal **67**. In such a manner, by employing an uneven lead frame **60** having, it is possible to secure the insulation property between different potentials.

The uneven lead frame **60** is not limited to the above example. For example, as in a modification shown in FIG. **18**, in the lead frame **60**, the connection portion **62**E of the main terminal **61**E may be locally thickened. In the lead frame **60**, the connection portion **62**E is a thick portion, and the other is a thin portion. The plate surface close to the semiconductor element **40** in the connection portion **62**E is substantially flush with the extension portion **63**E and the like.

Thereby, a facing distance D**4** between the lead frame **60** and the mounting surface **500**E of the heat sink **50**E can be made longer than that of the example shown in the preceding embodiments. Accordingly, when the sealing resin body **30** is molded, the resin easily flows between the lead frame **60** and the mounting surface **500**E. Thereby, it is possible to avoid molding defects of the sealing resin body **30** while achieving the effect of reducing the inductance. It can also be applied to a configuration in which the signal terminal **67** is connected to the pad **42** via the bonding wire.

The plate surface close to the heat sink **50**E in the connection portion **62**E may be substantially flush with the extension portion **63**E and the like. In this case, although the main terminal **61**E is away from the mounting surface **500**C, it is possible to reduce the inductance as compared with the above comparative example. Further, the resin easily flows between the lead frame **60** and the mounting surface **500**C.

Other Embodiments

Although an example in which the semiconductor device **20** is applied to the inverter **5** has been described, the present embodiment is not limited to the above example. For example, the present embodiment may be applied to a converter. The present embodiment may also be applied to both the inverter **5** and the converter.

The example in which the IGBT **6***i* and the FWD **6***d* are formed on the semiconductor element **40** has been shown. However, it is not limited to this. The FWD **6***d* may be used as a separate chip.

The example in which the IGBT **6***i* is shown as the switching element has been shown. However, it is not limited to this. For example, a MOSFET can be employed.

The example in which the heat dissipation surfaces **501**C and **501**E are exposed from the sealing resin body **30** has been shown. However, it is not limited to this. At least one of the heat dissipation surfaces **501**C and **501**E may be covered with the sealing resin body **30**. The heat dissipation surfaces **501**C and **501**E may be covered with an insulating member (not shown) different from the sealing resin body **30**.

Although not shown, a through hole may be provided in the lead frame **60** at a portion facing the heat sink **50**. Thereby, it is possible to avoid molding defects. A through hole may be provided in the main terminal **61**. For example, it may be provided in the common portion **640**E. The through hole may be provided in the signal terminal **67**. The through hole may be provided in the suspension lead **68**.

In the above, the embodiments, the configurations, the aspects of the semiconductor device according to the present disclosure are exemplified. The present disclosure is not limited to the above-described embodiments, each configuration and each aspect related to the present disclosure. For example, embodiments, configurations, and examples obtained from an appropriate combination of technical elements disclosed in different embodiments, configurations, and examples are also included within the scope of the embodiments, configurations, and examples of the present disclosure.

What is claimed is:

1. A semiconductor device comprising:

a semiconductor element having one surface and a back surface opposite to the one surface in a thickness direction of the semiconductor element, the semiconductor element including a first main electrode placed on the one surface and a second main electrode placed on the back surface;

a first heat dissipation member and a second heat dissipation member placed to sandwich the semiconductor element, the first heat dissipation member placed close to the one surface and connected to the first main electrode, the second heat dissipation member placed close to the back surface; and

a lead frame including at least one first main terminal electrically connected to the first heat dissipation member and a second main terminal connected to the second main electrode, wherein

the second main terminal includes a connection portion, a facing portion, and at least one non-facing portion,

the connection portion is connected with the second main electrode;

the facing portion extends from the connection portion, has a first end continuous from the connection portion and a second end continuous from the at least one non-facing portion, and faces the first heat dissipation member,

the at least one non-facing portion and the at least one first main terminal are arranged in a direction orthogonal to the thickness direction,

the second heat dissipation member is connected to the semiconductor element via the second main terminal,

in the lead frame, the at least one first main terminal includes a plurality of first main terminals or the at least one non-facing portion of the second main terminal includes a plurality of non-facing portions, and

the at least one first main terminal and the at least one non-facing portion of the second main terminal are alternately arranged in such a manner that a side surface of one of the at least one first main terminal faces a side surface of adjacent one of the at least one non-facing portion of the second main terminal to form a plurality of pairs of the side surfaces that face each other.

2. The semiconductor device according to claim **1**, wherein

the second main terminal includes the plurality of non-facing portions and the connection portion integrally provided with the plurality of non-facing portions.

3. The semiconductor device according to claim **2**, wherein

the facing portion is integrally provided with the plurality of non-facing portions in at least a part of a range in an extension direction in which the facing portion extends from the connection portion.

4. The semiconductor device according to claim **1**, wherein

the semiconductor element further includes a signal pad formed on the back surface, and

the lead frame further includes a signal terminal electrically connected to the pad.

5. The semiconductor device according to claim **4**, wherein

the signal terminal is connected to the pad via a joint member.

6. The semiconductor device according to claim **5**, wherein

in the lead frame, the signal terminal is thinner than the second main terminal, and

a facing distance between the signal terminal and the first heat dissipation member is longer than a facing distance between the second main terminal and the first heat dissipation member.

7. The semiconductor device according to claim **1**, wherein

the first heat dissipation member includes an overlapping portion that overlaps with the second heat dissipation member in a plan view from the thickness direction and a non-overlapping portion that is continuous from the overlapping portion and does not overlap with the second heat dissipation member, and

the first main terminal is connected to the non-overlapping portion of a facing surface of the first heat dissipation member, the facing surface facing the second heat dissipation member.

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